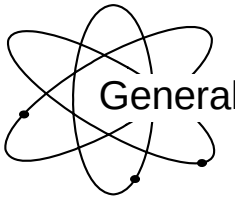
US Army Corps of Engineers
Hydrologic Engineering Center



SGSWG
Statistical & Graphical Analyses of Stream Water Quality Data

User's Manual

July 1987

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CPD-12

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I. INTRODUCTION

Background

The Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers possesses and commonly uses a computer model capable of analyzing either dynamic or steady-state water quality interactions in river-reservoir systems. This model has been developed over the years by numerous consulting engineering firms as discussed in reference (1), and is called the "Water Quality For River-Reservoir Systems" (WQRRS) Model.

Because of the volume of output generated by the Stream Quality Module of the WQRRS Model, there has existed a need to develop methods to assist users in interpretting and displaying the output of this module. As a consequence, over the past several years the HEC has developed a preliminary plotting routine and statistical program to accomplish these goals. These programs have been finalized by Tetra Tech, Inc., and are described herein. The resulting programs are compositely called the Stream Water Quality Post-Processor.

Project Organization

Dr. Marc W. Lorenzen served as principal-in-charge, and Mr. William B. Mills served as project manager for Tetra Tech. All computer programming was performed by Mr. Larry Woods of Tetra Tech. Mr. Steve Gherini, also of Tetra Tech, aided in the preparation of the final report.

Mr. R. G. Willey of the Hydrologic Engineering Center served as project officer, and provided technical assistance. Mr. Al Onodera and Paul Ely of HEC also provided technical input.

General Capabilities of the Post-Processor

The Stream Water Quality Post-Processor now consists of three major components: two plotting programs and a statistical program. Each of these programs can be executed independently of the other two, and each accepts input from a tape containing selected output of the Stream Quality Module. Additionally, cards containing observed data can be read in with each program and comparisons can then be made between the simulated and observed data. The capabilities of the three programs will be discussed in detail in the chapters describing each component of the post-processor, but their overall capabilities will be summarized here.

Each of the three programs can analyze up to eleven water quality parameters. The parameters are:

- streamflow
- water temperature
- dissolved oxygen
- ammonia nitrogen
- nitrate nitrogen
- phosphate phosphorus
- alkalinity
- coliforms
- total dissolved solids
- pH
- 5-day biochemical oxygen demand

The first plotting program plots the results of the stream simulations as a function of time for any number of these eleven parameters at user specified locations throughout the study reach. The user has the option to superimpose observed values on these plots.

Water quality standards can be specified and plotted as well. In the case of temperature and pH, both maximum and minimum standards values can be plotted.

The second plotting program plots longitudinal profiles of water quality parameters at all nodes throughout the study reach. For each of the eleven parameters, plots of the maximum and/or minimum simulated values over the study period at each node can be generated. The user can specify that observed data and water quality standards be plotted as well. The water quality standards can be changed as a function of river mile to reflect different stream segment quality designations. As a separate option, the user can also input cards containing values of the water quality parameters that are indicative of a particular critical quality condition. The mean error and standard deviation associated with these critical values can also be plotted. The input values for this option generally come from the results of the statistical program.

The statistical program has the capability of summarizing by node the maximum, minimum, mean, and standard deviation of the simulated values over the study period, or over a selected subperiod for each of the eleven water quality parameters. It can also compare simulated parameter values against selected water quality standards and determine the number and percent of points exceeding the selected standards. Lastly, it can accept observed data via card input for various locations throughout the study reach and then determine the mean and standard deviation of the difference between the simulated and observed values.

The two plotting programs have been written to use standardized Cal-Comp software, and all three programs have been successfully

tested on the CDC 7600 and the UNIVAC 1108. Unfortunately, Cal-Comp software is not completely standardized between installations, and this may necessitate that the user institute minor program changes depending on the computer facility being used. The locations of possible coding changes are discussed in the chapters dealing with the plotting programs. Comments have been incorporated into the two plotting programs to facilitate the adaptation of the programs to any installation.

II. WATER QUALITY VERSUS TIME PLOTTING PROGRAM

Description of Capabilities

This component of the post-processor plots water quality parameters at specified locations within the study reach and over the time period for which results are contained on the output tape from the WQRRS model. A summary of each of the capabilities of the program follows. The capabilities will later be demonstrated by an illustrative test case. The word "simulated" in the following discussion is to be associated with the output generated by the WQRRS model, while the word "observed" is to be associated with measured values, and is not related to model output.

The capabilities of this plotting program are:

1. The program plots up to 11 water quality parameters (including flow) at any selected node within the study reach. Any combination of the eleven parameters can be plotted at a location. The parameters normally are contained on tape in the following order, and are plotted with the units indicated:

    - streamflow, 1000's cfs
    - water temperature, °C
    - dissolved oxygen, mg/l
    - ammonia nitrogen, mg-N/l
    - nitrate nitrogen, mg-N/l
    - phosphate phosphorus, mg-P/l
    - alkalinity, mg/l as $CaCO_3$

- log coliforms, log MPN/100 ml
- total dissolved solids, mg/l
- pH
- 5-day biochemical oxygen demand, mg/l

2. The same simulated water quality parameters that are selected for plotting at one node are also plotted at all other nodes selected for plotting.

3. Plots can be generated for up to five locations within the study reach.

4. The simulated results are stored on tape at intervals of 2 to 24 hours, constant for the entire tape. A time interval for plotting can be chosen which is an integral multiple of this storage time interval.

5. The horizontal axis of the plots is always labeled in Julian days. Even if values are plotted every two hours, hourly indicators are not labeled. Tick marks are shown at midday, however, and grid lines are drawn at the beginning and end of each day to facilitate the location of points on the plots.

6. Observed data for the same 11 water quality parameters can be plotted at any or all of the five or less locations at which simulated data are plotted.

7. When observed data are plotted at a particular node for a particular parameter, simulated data are also plotted for that parameter. However, at the same location, simulated data may be plotted for some parameters for which no observed data are plotted.

8. The number of observed data points can vary by location and by parameter. The total number of data points at any one location may not exceed 50.

9. A line showing a water quality standard can be plotted for each water quality parameter. For temperature and pH, two lines can be plotted that show maximum and minimum standards (if specified). The standard must remain constant during the plotting time period.

10. For each execution of the program, exactly one reach can be analyzed. If more than one reach is to be analyzed, then sequential program runs must be made. A reach, as used in this report, is a continuous portion of a river system whose hydraulic and quality characteristics can be analyzed by the WQRRS model. An entire river system may be analyzed by dividing it into several reaches. Figure II-1 shows how the Oconee River in Georgia was divided into five reaches and then analyzed using the WQRRS model (2). For a more detailed description of the term "reach", reference (1) can be consulted.

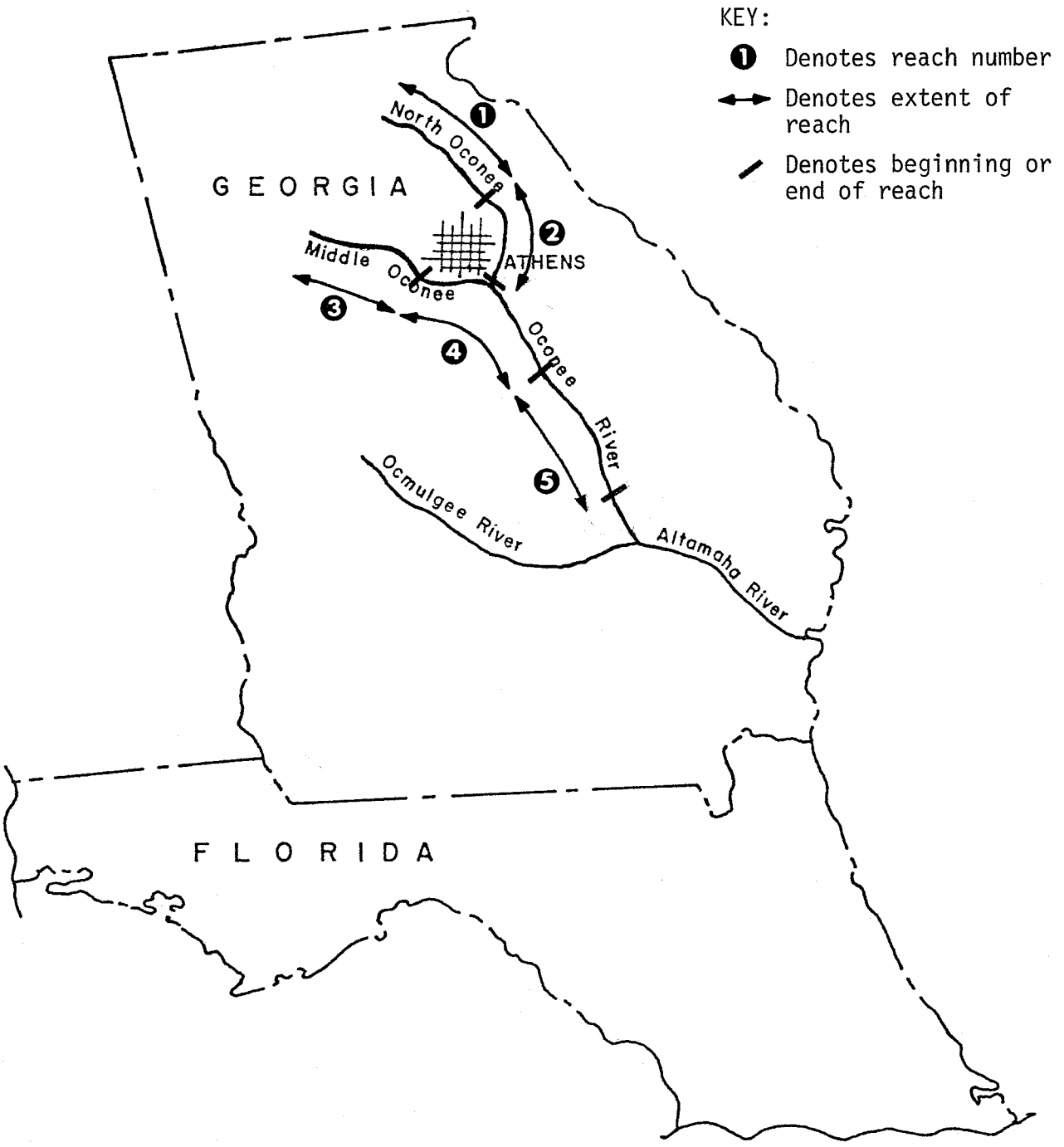


Figure II-1. Division of the Oconee River into Reaches for Analysis by the WQRRS Model

11. Because of variations of Cal-Comp software between computer installations, several of the subroutines comprising the program contain cards that are installation-dependent. These subroutines are: INITPL, NEXTFR, and STOPPL. Their functions are described in the next section. The program code itself contains comment cards describing the functions of these routines, and indicates that they are system-dependent. Additionally the call to subroutine AXIS from the main program has different numbers of arguments depending on the installation being used. In testing this program it was found that the first eight arguments were the same at both installations. If a ninth argument is specified which defines the number of 90° rotations to be performed before drawing the axis, this integer argument should be set to zero.

Description of Subroutines

PROGRAM WQPLOT is the main subroutine controlling operation of the plotting program, as shown in Figure II-2. This routine first reads data from input cards and then reads the simulated results from tape and stores them temporarily on disk files to be read as needed. It then calls other subroutines that actually create the plots.

SUBROUTINE RJDC packs one array of hollerith characters in nA1 format into another array in which each computer word contains as

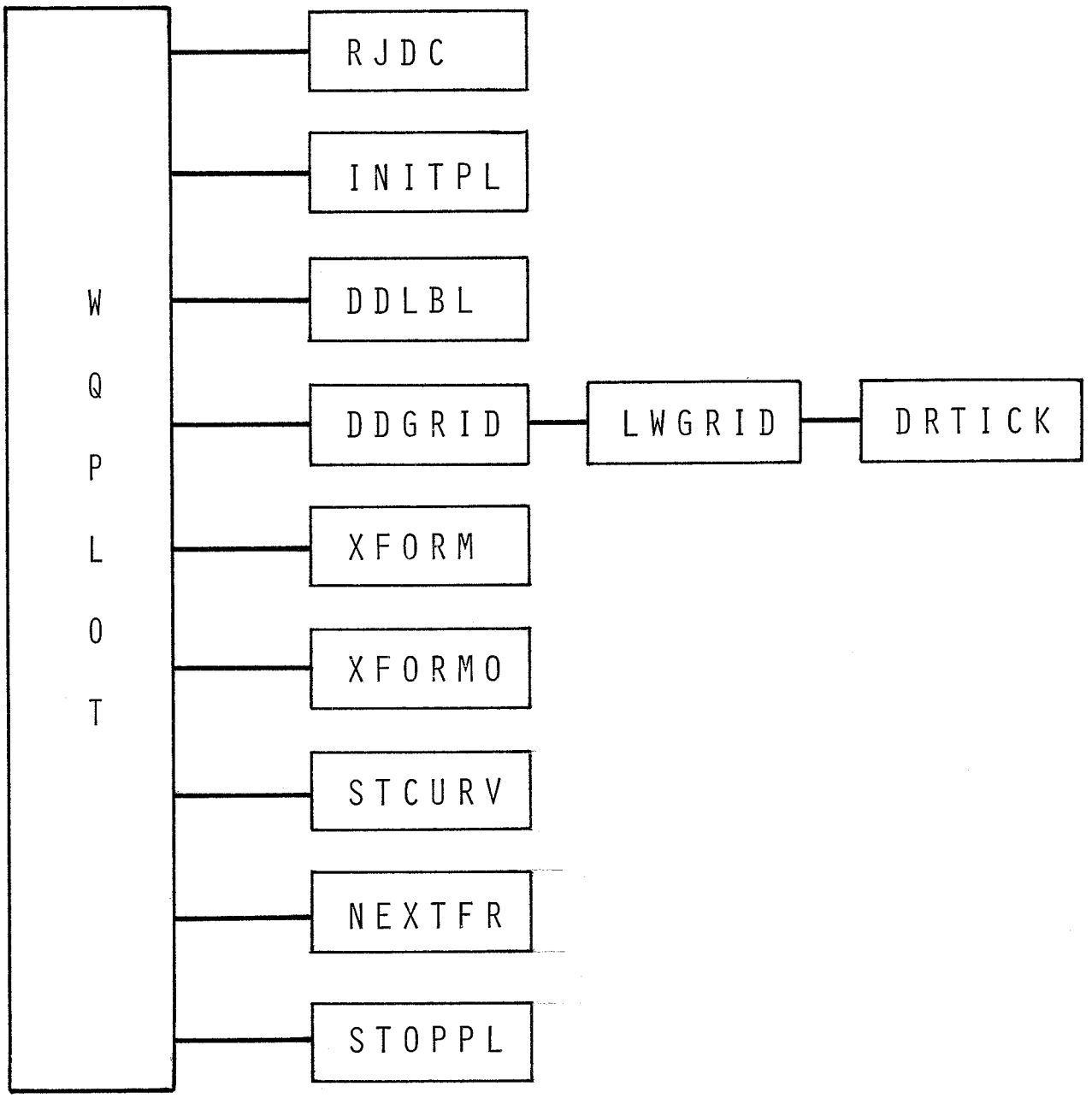


Figure II-2. Subroutines Comprising the Water Quality Versus Time Plotting Program

many characters as the computer word size allows (4 or 6, for example). This routine removes leading and trailing blanks from the hollerith constants, and it also returns the number of non-blank characters found (imbedded blanks in a string are counted as non-blank).

SUBROUTINE INITPL initializes the plotting device. It is a separate subroutine because portions of its code are installation-dependent.

SUBROUTINE DDLBL writes Julian day numbers along the horizontal axis.

SUBROUTINE DDGRID draws the grid lines and tick marks used for each plot. It calls LWGRID four times (once each for the lower horizontal axis, the upper horizontal axis, the left vertical axis, and the right vertical axis).

SUBROUTINE LWGRID draws grid lines and tick marks along one axis by repeatedly calling DRTICK.

SUBROUTINE DRTICK moves the plotter pen one increment of distance along a given axis and then draws a line of specified length perpendicular to that axis. This line could be either a tick mark or a grid line.

SUBROUTINE XFORM performs any necessary data transformations on simulated data such as conversion of flow units.

SUBROUTINE XFORMO performs any necessary data transformations on observed data.

SUBROUTINE STCURV draws minimum and/or maximum standards curves (straight horizontal lines) on a plot, provided that standards values are specified.

SUBROUTINE NEXTFR advances the plotter to the next frame. It is a separate routine because the code can vary from installation to installation.

SUBROUTINE STOPPL terminates all plotting activity. It also is a separate routine because the code is installation-dependent.

Card Format

This section contains a detailed description of every variable on each input card. These descriptions will be found in Table II-1 which follows this discussion. Figure II-3 at the end of the section shows the sequential arrangement of input cards for this plotting routine.

All variables, except plot and axes titles, are specified by fields of eight columns each. Titles are given as nA1 format. Field 1 of each card is always reserved for card identification, and must be left justified.

The range of values a variable may assume and the corresponding interpretations are described below. Some variables simply indicate the program option to be used by specifying discrete numbers. For those variables having a + sign shown under the column "value," the numerical value of the variable is entered as input. Where the value is zero, the corresponding input field may be left blank.

Data for variables beginning with the letters I through N are integers and should not include decimals, but should be right justified in their field. Data for variables beginning with letters A through H and O through Z are floating point variables and should be right justified in their field if the decimal points are not punched. Variable names for plot and axes titles may begin with any letter, and may begin in any column within their specified field.

The simulated results of the Stream Quality Module are read from tape once the required data cards have been read. A detailed understanding of how the program reads data from the tape is not required of the user. However, the user does need to know which parameters are stored on tape and their order because some of this information must be specified on certain input cards. (See p. II-1 for the order in which the parameters are normally stored on the WQRRS output tape.)

It is of interest to the user to note that, at the time of this writing, an additional variable is being written onto tapes containing the stream water quality results which is not present on earlier tapes. This additional variable specifies the river reach, and is contained in the first field of each record on the tape. Otherwise, the information stored on the new and old tapes is identical. The effect of this is that tapes containing results that do not have a reach specification cannot be processed using this program without modifying both the tape read statement contained in this program, and the program logic that checks for the desired reach number.

TABLE II-1

DETAILED DESCRIPTIONS OF INPUT CARDS
FOR WATER QUALITY VERSUS TIME PLOTTING PROGRAM

Title Description Card*

Field	Variable	Value	Description
1		TITLE	Card identification.
2-4	TIT1(1) to TIT1(20)**	alpha(A1)	TIT1 and TIT2 comprise the plot title for all frames in a run. This identifies the river system and reach under study (e.g., YORK RIVER).
4-6	TIT2(1) to TIT2(20)**	alpha(A1)	

*This card and all remaining cards in this description are required cards unless the specific card description defines it as being optional.

**TIT1 ends in field 4 and TIT2 begins in field 4.

TABLE II-1
(CONTINUED)

Job Description Card 1

Field	Variable	Value	Description
1		JOB1	Card identification.
2	NPTAPE	+	Number of parameters on tape (from 1 to 11).
3	NPAR	+	Number of parameters to be plotted (from 1 to NPTAPE).
4	NS	+	Number of nodes in the reach.
5	NPTS	+	Number of nodes for which simulated results are to be plotted ($\leq$5).
6	NOBS	+	Number of nodes where there are observed data (from 0 to 5).
7	NHHI	+	Number of hours between points to be plotted (from 2 to 24).*
8	NHHIT	+	Number of hours between simulated values stored on tape (from 2 to 24).
9	NUMDY	+	Number of days for which results are stored on tape ($\geq$1).
10	INTDY	+	Number of days per plot.**

*NHHI must be an integral multiple of NHHIT.

**For example, if NUMDY=60 and INTDY=20, three plots are generated for one water quality parameter. This relationship controls the scale of the horizontal axis.

TABLE II-1
(CONTINUED)

Job Description Card 2

Field	Variable	Value	Description
1		JOB2	Card identification.
2	LNGTH	+	Length of horizontal axis in hundredths of inches. LNGTH must equal INTDY (JOB1 card, field 10) times any integer times ten.
3	INTP	+	Logical unit number of simulated data file.*
4	IOTMP	+	Lowest of five consecutive logical unit numbers to be used for temporary storage files.*
5	IFLOW	1	For observed flow in m^3/s.**
		≠1	For observed flow in cfs.**
6	IREACH	+	Reach number for which plots are to be generated.
7	INGRID	0	Normal grid plotted.
		1	Grid eliminated. This option may be used for making overlays for color reproduction of graphical outputs.

*Any unit number acceptable to the user's computer system may be used. The numbers used may need to be assigned a magnetic tape or disk name using the specific job control language for the user's computer system.

**If there are no observed values for stream flow, IFLOW does not have to be specified.

TABLE II-1
(CONTINUED)

Job Description Card 2

Field	Variable	Value	Description
8	INCDY	0	Every day labeled on graphical output.
		+	Magnitude of increment for labeling graphical output. This option is needed when the horizontal distance per day is too small for a daily label.
9	INCLIN	0	A vertical line at the end of each day.
		+	Magnitude of increment for vertical lines. This option is used to produce an "open grid."
10	INCTIC	0	Four tic marks or subdivisions per vertical inch on the Y axis.
		+	Number of tic marks or subdivisions per vertical inch on the Y axis.

TABLE II-1
(CONTINUED)

Job Description Card 3*

Field	Variable	Value	Description
1		JOB3	Card identification.
2	PLOCS(I)	+	River mile where simulated results are to be plotted.
3	RV(1,I) to RV(8,I)	**	Title given to all plots at this river mile (e.g., RIVER MILE 31.5).
.	.		
.	.		
.	.		
7	RV(33,I) to RV(40,I)	**	

*There should be NPTS (JOB1 card, field 5) JOB3 cards.

**RV is in 40A1 format.

Job Description Card 4†

Field	Variable	Value	Description
1		JOB4	Card identification.
2	IPAR(I)	+	The number of the parameter on tape which is to be plotted. IPAR(I) is less than or equal to NPTAPE (JOB1) card, field 2).††
3	PSCAL1(I)	+	Minimum value of IPAR(I) for plotting purposes.
4	PSCAL2(I)	+	Maximum value of IPAR(I) for plotting purposes.

†There are NPAR (JOB1 card, field 3) JOB4 cards.

††For example, if the fifth parameter stored on tape is the first parameter to be plotted, then IPAR(1)=5.

TABLE II-1
(CONTINUED)

Job Description Card 5*

Field	Variable	Value	Description
1		JOB5	Card identification.
2-4	GRLBLE(1,J) to GRLBLE(20,J)**	alpha(A1)	Title to be given to all plots of this parameter (e.g., WATER TEMPERATURE).
4-6	YLBUL(1,J) to YLBUL(15,J)**	alpha(A1)	Vertical axis label for all plots of this parameter (e.g., DEG C).

*There are NPAR (JOB1 card, field 3) JOB5 cards.

**There is some overlap in field 4 between the last value of GRLBLE and the first value of YLBUL.

Standards Description Card† - Standards for coliforms are input as log MPN/100 ml.

Field	Variable	Value	Description
1		STAN	Card identification.
2	STAND(1,IR,IPQ)	+	Minimum standard for the IRth node and IPQth parameter.††
3	STAND(2,IR,IPQ)	+	Maximum standard for the IRth node and IPQth parameter.††

†There are NPTS*NPAR (JOB1 card, fields 3 and 5) STAN cards.

††If no standards value is specified, the field should be left blank. The standards should be specified for the same parameter at all nodes before changing parameters (i.e., the variable IR varies faster than the variable IPQ).

TABLE II-1
(CONTINUED)

Observed Data Description Card* - include only if NOBS (JOB1 card, field 6) ≠0. Otherwise, no more input cards are required for this program.

Field	Variable	Value	Description
1		OBS1	Card identification
2	RIV	+	River mile where observed data occur (must be the same as a location where simulated data exist).
3	N	+	Total number of distinct times at which observed data were recorded at this river mile.

*This card and the corresponding OBS2 and OBS3 cards appear as a set NOBS (JOB1 card, field 6) times.

TABLE II-1
(CONTINUED)

Observed Data Description Card 2* - Include only if NOBS (JOB1 card, field 6) ≠0. Otherwise, no more cards are required for this program input. Observed coliform data are input as log MPN/100 ml.

Field	Variable	Value	Description
1		OBS2	Card identification.
2	JDAY	+	Julian date this observation was made. See Appendix A to convert calendar date to Julian date.
3	JHRS	+	Hour (an integer from 0 to 24) this observation was made.
4	OBSRV(1,J,K)	+	Observed data values for the first 7 parameters or first NPTAPE (JOB1 card, field 2) parameters, if NPTAPE is less than 7. A missing value is denoted by a blank. If a true zero is observed, a small positive number must be entered instead.
.			
.			
.			
10	OBSRV(7,J,K)	+	

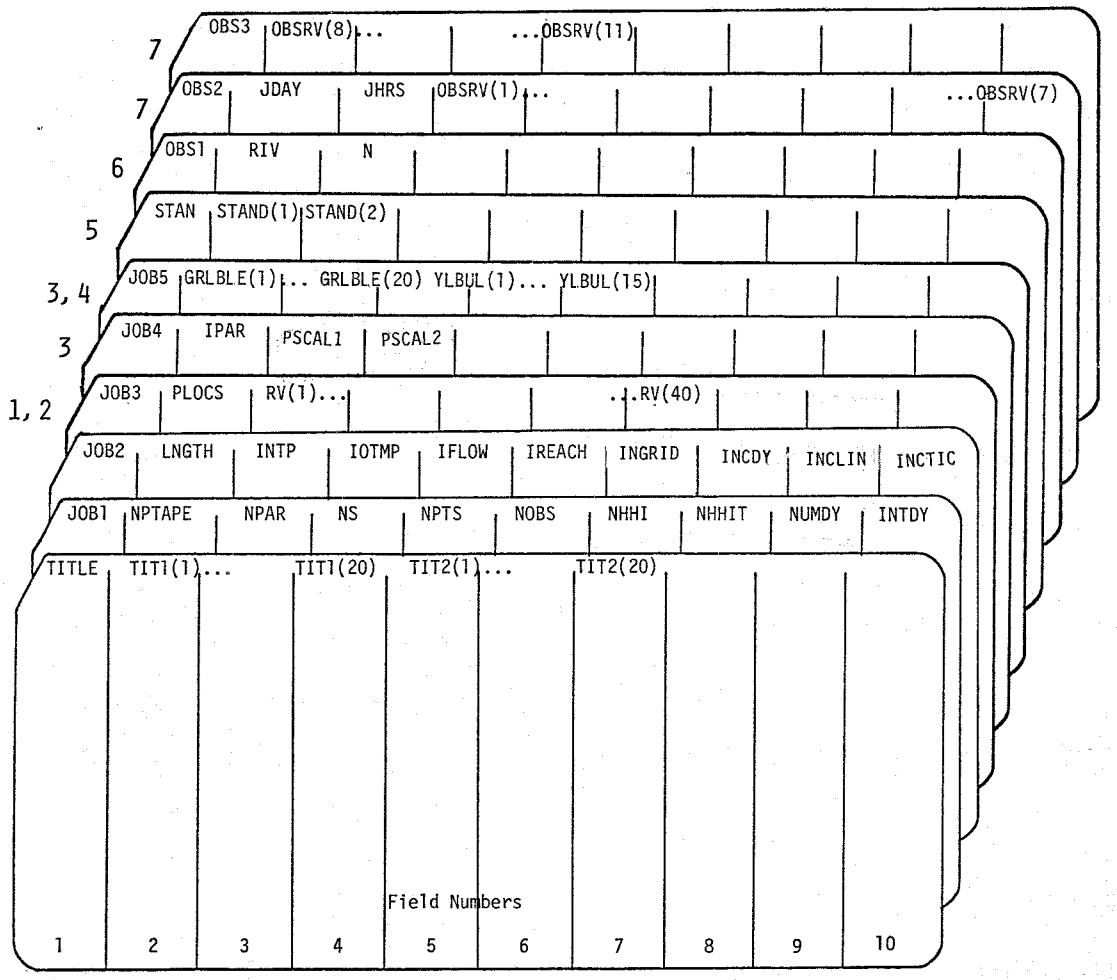
*For a given river mile there are N (OBS1 card, field 3) OBS2 and OBS3 cards. If the number of observed parameters is less than 8, however, the OBS3 card is omitted entirely, regardless of the value of N. The OBS1 card, and this entire sequence of OBS2 and OBS3 cards, appear NOBS (JOB1 card, field 6) times.

TABLE II-1
(CONTINUED)

Observed Data Description Card 3* - Include only if NOBS (JOB 1 card, field 6) ≠0 and the number of observed parameters exceeds 7. Observed coliforms are input as log MPN/100 ml.

Field	Variable	Value	Description
1		OBS3	Card identification.
2	OBSRV(8,J,K)	+	Values of the observed parameters 8 through NPTAPE (JOB1 card, field 2) when NPTAPE exceeds 7. A missing value is denoted by a blank. If a true zero is observed, a small positive number must be entered instead.
.			
.			
.			
5	OBSRV(11,J,K)	+	

*See the footnote pertaining to the OBS2 card.



NOTE 1. There are NPTS (JOB1 card, field 5) JOB3 cards.

NOTE 2. Each element of the array RV occupies 1 column. Hence, 40 elements of RV occupy 5 fields (3 through 7).

NOTE 3. There are NPAR (JOB1 card, field 3) JOB4 and JOB5 cards.

NOTE 4. GRLBLE occupies 20 spaces beginning in column 9; YLBUL occupies 15 spaces beginning in column 29.

NOTE 5. There are NPTS*NPAR (JOB1 card, fields 3 and 5) STAN cards.

NOTE 6. There are NOBS (JOB1 card, field 6) OBS1 cards. Before the OBS1 card is repeated, N (OBS1 card, field 3) OBS2 and OBS3 cards follow which pertain to the river mile, RIV, on the present OBS1 card.

NOTE 7. There are N (OBS1 card, field 3) OBS2 and OBS3 cards (the OBS3 card may be unnecessary depending on the number of parameters observed).

Figure II-3. Card Sequence for the Water Quality Versus Time Plotting Program

Application of Plotting Program

This plotting program has been applied to reach 3 of the Middle Oconee River (river mile 31.5 to 17.0) near Athens, Georgia using simulated results obtained during a study of the river from 1 October 1970 through 31 October 1970. The observed data that are used for this test case are hypothetical and are used to illustrate the program's capabilities.

Input

Figure II-4 shows the arrangement of the input data chosen for this system. The TITLE card identifies the river system under study. The next two cards, the JOB1 and JOB2 cards, contain information specifying what the user wants plotted, how it is to be plotted, and on what unit the data are stored.

In this example, all eleven parameters are stored on tape, and plots are generated for all eleven parameters. Within the study reach there are 30 nodes, and at five of these both simulated results and observed data are plotted. The results are stored on the tape at two-hour intervals and are also plotted at two-hour intervals. Data for all 31 days for each parameter are plotted on one 8 inch plot. The data are stored on unit number 20 and units 1 through 5 are used for temporary storage files. The observed flow is input as cfs (since IFLOW $\neq$1).

The JOB3 card shows the river mile where simulated results are plotted (in this case river miles 31.5, 29.0, 25.5, 19.5, and 17.0) and the plot titles (as contained in RV) identifying these locations.

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQPLOT DATE

REQUESTED BY R.G. WILLEY PREPARED BY CHECKED BY PAGE 1 OF 7

	1	2	3	4	5	6	7	8	9	10
TITLE	OCONEE RIVER, GA.			REACH 3						
JOB1	1	1		30	5	5	2	2	31	31
JOB2	8	20		1	0	3				
JOB3	31.5MILE 31.5									
JOB3	29.0MILE 29.0									
JOB3	25.5MILE 25.5									
JOB3	19.5MILE 19.5									
JOB3	17.0MILE 17.0									
JOB4	1									
JOB4	2									
JOB4	3									
JOB4	4									
JOB4	5									
JOB4	6									
JOB4	7									
JOB4	8									
JOB4	9									
JOB4	10									
JOB4	11									
JOB5	STREAM FLOW			1000 CFS						
JOB5	WATER TEMPERATURE			DEG C						
JOB5	DISSOLVED OXYGEN			MG/L						
JOB5	AMMONIA			MG/L AS N						
JOB5	NITRATE			MG/L AS N						
JOB5	PHOSPHATE			MG/L AS P						
JOB5	ALKALINITY			MG/L CACO3						
JOB5	LOG COLIFORM			LOG MPN/100ML						
JOB5	DISSOLVED SOLIDS			MG/L						
JOB5	PH									
JOB5	BOD5			MG/L						

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Figure II-4. Coding Sheets Showing Sample Input Data for Water Quality Versus Time Plotting Program

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

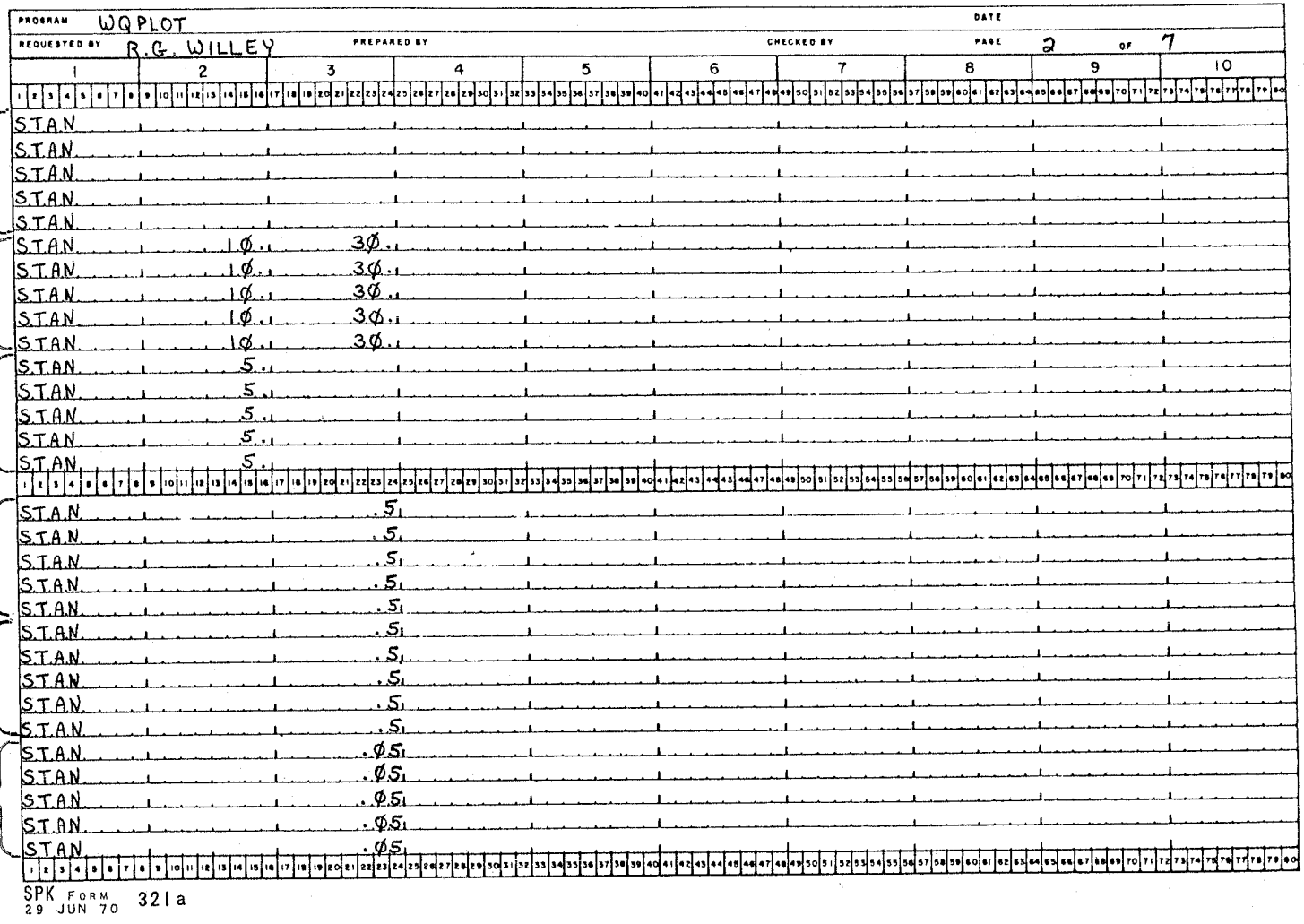

Figure II-4 (Continued)

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQPLOT DATE

REQUESTED BY R.G. WILLEY PREPARED BY CHECKED BY PAGE 3 OF 7

	1	2	3	4	5	6	7	8	9	10
Alkalinity	STAN									
	STAN									
	STAN									
	STAN									
	STAN									
Log Coliforms	STAN		3.38							
	STAN		3.38							
	STAN		3.38							
	STAN		3.38							
	STAN		3.38							
Dissolved Solids	STAN		500.							
	STAN		500.							
	STAN		500.							
	STAN		500.							
	STAN		500.							
pH	STAN	5.5	9.0							
	STAN	5.5	9.0							
	STAN	5.5	9.0							
	STAN	5.5	9.0							
	STAN	5.5	9.0							
BOD_5	STAN		5.							
	STAN		5.							
	STAN		5.							
	STAN		5.							
	STAN		5.							
Observed Data at RM 31.5	OBS1	31.5	11							
	OBS2	274	0	90.0	19.0	8.5	0.09	0.55	0.05	26.1
	OBS3	2.96	110.	7.5	.59					
	OBS2	275	4	88.5	18.5	8.2	0.08	0.50	0.05	26.0
	OBS3	3.38	110.	7.0	.40					

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Figure II-4 (Continued)

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQPLOT DATE

REQUESTED BY R.G. WILLEY PREPARED BY CHECKED BY PAGE 4 OF 7

	1	2	3	4	5	6	7	8	9	10
	OBS 2	27 7	12	85.5	17.0	8.1	.08	.55	.06	25.5
	OBS 3	2.96	7.3	.35						
	OBS 2	280	21	80.0	17.5	8.1	.09	.59	.05	26.0
	OBS 3	3.38	7.0	.31						
	OBS 2	289	17	115.0	14.0			.55	.06	25.1
	OBS 3		7.5	.35						
	OBS 2	289	19			8.0	.09			
Observed Data at RM 31.5	OBS 3	3.38								
	OBS 2	293	8	125.0			.10	.50		
	OBS 3	2.96								
	OBS 2	296	3	200.0			.09	.65		
	OBS 3	2.96								
	OBS 2	299	24	225.0			.14	.66		
	OBS 3	2.96								
	OBS 2	303	5	205.0			.15	.58		
	OBS 3	2.96								
	OBS 2	304	24	360.0			.11	.55		
	OBS 3	2.96								
	OBS 1	29.0	5							
	OBS 2	274	4	110.0	18.0	9.5				
	OBS 3	2.96		30						
Observed Data at RM 29.0	OBS 2	28 1	21	100.0	18.5	9.6				
	OBS 3	3.20		.31						
	OBS 2	291	7	100.0	11.0	10.1				
	OBS 3	3.20		.25						
	OBS 2	300	16	190.0	13.5	9.0				
	OBS 3	2.96		.28						
	OBS 2	304	16	450.	17.5	8.5				
Observed Data at RM 25.5	OBS 3			.10						
	OBS 1	25.5	5							

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Figure II-4 (Continued)

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQPLOT DATE

REQUESTED BY R.G. WILLEY PREPARED BY CHECKED BY PAGE 5 OF 7

	1	2	3	4	5	6	7	8	9	10
OBS 2		276	12		24.Ø	8.5			.Ø9	
OBS 3			9Ø.							
OBS 2		284	7		18.Ø	9.Ø			Ø6	
OBS 3			9Ø.							
OBS 2		296	3		14.1	9.3			1.1	
OBS 3			11Ø.							
OBS 2		3ØØ	15			1Ø.1			Ø9	
OBS 3			1Ø5.							
OBS 2		3Ø4	23			8.5			.Ø7	
OBS 3										
OBS 1		19.5	33							
OBS 2		274	Ø	15Ø.	2Ø.5	8.5	.Ø8	.25	Ø9	25.
OBS 3		3.20	1ØØ.	7.5	Ø.5					
OBS 2		275	4	155.	19.1	9.Ø	.14	.65	.14	24.
OBS 3		2.96	11Ø.	7.6	1.3					
OBS 2		276	7	142.	17.Ø	9.6	.15	.65	.14	25.1
OBS 3		2.96	11Ø.	7.7	1.2					
OBS 2		276	24	135.	19.8	9.Ø	.16	.66	.13	29.Ø
OBS 3		2.96	1ØØ.	7.7	1.3					
OBS 2		277	21	13Ø.	21.5	8.5	.17	.69	.13	26.Ø
OBS 3		3.38	1Ø5.	7.5	1.2					
OBS 2		278	4	14Ø.						
OBS 3										
OBS 2		278	18	14Ø.						
OBS 3										
OBS 2		279	12	135.						
OBS 3										
OBS 2		279	2Ø	135.						
OBS 3										
OBS 2		28Ø	8	13Ø.						

Observed Data at RM 25.5

Observed Data at RM 19.5

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Figure II-4 (Continued)

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQPLOT DATE

REQUESTED BY R.G. WILLEY PREPARED BY CHECKED BY PAGE 6 OF 7

1	2	3	4	5	6	7	8	9	10
OBS3									
OBS2	280	24	130						
OBS3									
OBS2	281	12	135						
OBS3									
OBS2	281	20	135						
OBS3									
OBS2	282	10	140						
OBS3									
OBS2	282	22	142						
OBS3									
OBS2	283	6	150						
OBS3									
OBS2	283	22	151						
OBS3									
OBS2	284	10	152						
OBS3									
OBS2	284	18	153						
OBS3									
OBS2	285	6	152						
OBS3									
OBS2	285	18	150						
OBS3									
OBS2	286	6	150						
OBS3									
OBS2	292	22	155						
OBS3									
OBS2	293	4	270						
OBS3									
OBS2	293	16	190						

Observed Data at RM 19.5

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Figure II-4 (Continued)

GENERAL PURPOSE DATA FORM
(8 COLUMN FIELDS)

PROGRAM WQPLOT DATE
REQUESTED BY R. G. WILLEY PREPARED BY CHECKED BY PAGE 7 OF 7

OBS 3									
OBS 2	294	4	32Ø.						
OBS 3									
OBS 2	294	16	57Ø.						
OBS 3									
OBS 2	295	4	44Ø.						
OBS 3									
OBS 2	295	16	3Ø6.						
OBS 3									
OBS 2	295	24	275.						
OBS 3									
OBS 2	296	8	25Ø.						
OBS 3									
OBS 2	297	8	28Ø.						
OBS 3									
OBS 2	298	4	24Ø.						
OBS 3									
OBS 1	17.Ø	1							
OBS 2	3Ø4	24	35Ø.	17.Ø	8.5	.1Ø	65	.2Ø	24.
OBS 3	2.96	1ØØ.	7.3	.4Ø					

Observed Data at RM 19.5

Observed Data at RM 17.0

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Figure II-4 (Continued)

As shown by the 11 JOB4 cards, all water quality parameters are plotted. The identification of each parameter is specified by the variable GRLBLE on the JOB5 card (e.g., STREAM FLOW) and the vertical axis label is specified by YLBUL (e.g., 1000 CFS).

To illustrate a case where not all parameters are stored on tape and only a portion of those that are stored are to be plotted, consider the following instance. Suppose only streamflow, nitrate, and phosphate are contained on the tape, and that only nitrate and phosphate are to be plotted. In that case the JOB4 card would appear as follows:

```
JOB4      2
JOB4      3
```

This indicates that the second (nitrate) and third (phosphate) parameters stored will be plotted. The JOB5 card would then contain title information for these two nutrients, in the order they are to be plotted.

The STAN card indicates that the following standards were chosen for this test case:

water temperature	10°C minimum, 30°C maximum
dissolved oxygen	5 mg/l minimum
ammonia nitrogen	0.5 mg/l maximum
nitrate nitrogen	0.5 mg/l maximum
phosphate phosphorus	0.05 mg/l maximum
log coliform	3.38, log MPN/100 ml maximum
dissolved solids	500 mg/l maximum
pH	5.5 minimum, 9.0 maximum
BOD_5	5.0 mg/l maximum

Note that this card is repeated for each parameter to be plotted, even if a standard is not specified (such as for streamflow and alkalinity in this case). When a standard is not specified for a parameter to be plotted, a blank is left in the desired fields. For each parameter at each location to be plotted, both maximum and minimum standards must be entered on the STAN card (both entries could be blanks). Standards which are identically zero are not allowed. Standards can change from location to location, to reflect different water quality designations of different river reaches.

The remaining input cards deal exclusively with observed data, and if there are none, these cards (OBS1, OBS2, and OBS3) are omitted altogether. For the test case, observed data exist and are plotted at the same five river miles as for the simulated results (river miles 31.5, 29.0, 25.5, 19.5, and 17.0) as shown on the OBS1 cards. Note that the OBS2 and OBS3 cards pertaining to each river mile (such as 31.5) are inserted before the next OBS1 card is repeated. The OBS1 card also contains the number of unique sampling times. For example, at river mile 31.5, 11 observations were made, although no more than ten observations of any single parameter were made. It should also be noted that if the observed data were actually collected at a location near a node but not exactly at a node, such as river mile 31.4, the data have to be specified as being collected at a nearby node, such as river mile 31.5. Unless the variable RIV contains a node location, the observed data are not plotted for that location.

The OBS2 card specifies the date (Julian date) the observation was made, the hour of the day, and the observed data for up to the first seven parameters. If a parameter value was not observed, the entry is left blank. Also, if the hour and date of the observation

do not correspond to an hour and date specified to be plotted, the point is plotted at the closest time for which a simulated value is plotted. For example, the fourth observation at river mile 31.5 was made on day 280 at hour 21. Since hour 21 is not an hour for which simulated data are to be plotted, but hour 20 is, this observation will be plotted at hour 20 of that same day.

The OBS3 card follows the OBS2 card and contains the remainder of the parameters to be plotted for a single sampling date and hour. These two cards are then repeated for the remainder of the sampling dates and hours at the same river mile. At river mile 31.5, for example, there are a total of 11 pairs of these cards. This sequence of OBS1, OBS2, and OBS3 cards is repeated for each additional location where observations were taken.

Output

The output of this plotting program consists of plots generated by Cal-Comp software. Figures II-5 through II-7 illustrate the plotting capabilities. In general, simulated results are shown by the continuous wavy lines, while observed data points are depicted by the triangles. Water quality standards are shown as horizontal straight lines, with the word 'MAX' bracketing the maximum standards line and the word 'MIN' bracketing the minimum standard line.

Figure II-5 shows a plot of streamflow over the period of record, Julian day 274 through 304, or equivalently, 1 October through 31 October, at river mile 19.5 of the Oconee River, reach 3. The plot contains both observed and simulated flow data. The title, "OCONEE RIVER, GA. REACH 3," was generated by the TITLE card, "MILE 19.5" by the JOB3 card, and "STREAM FLOW" by the JOB5 card. Grid lines

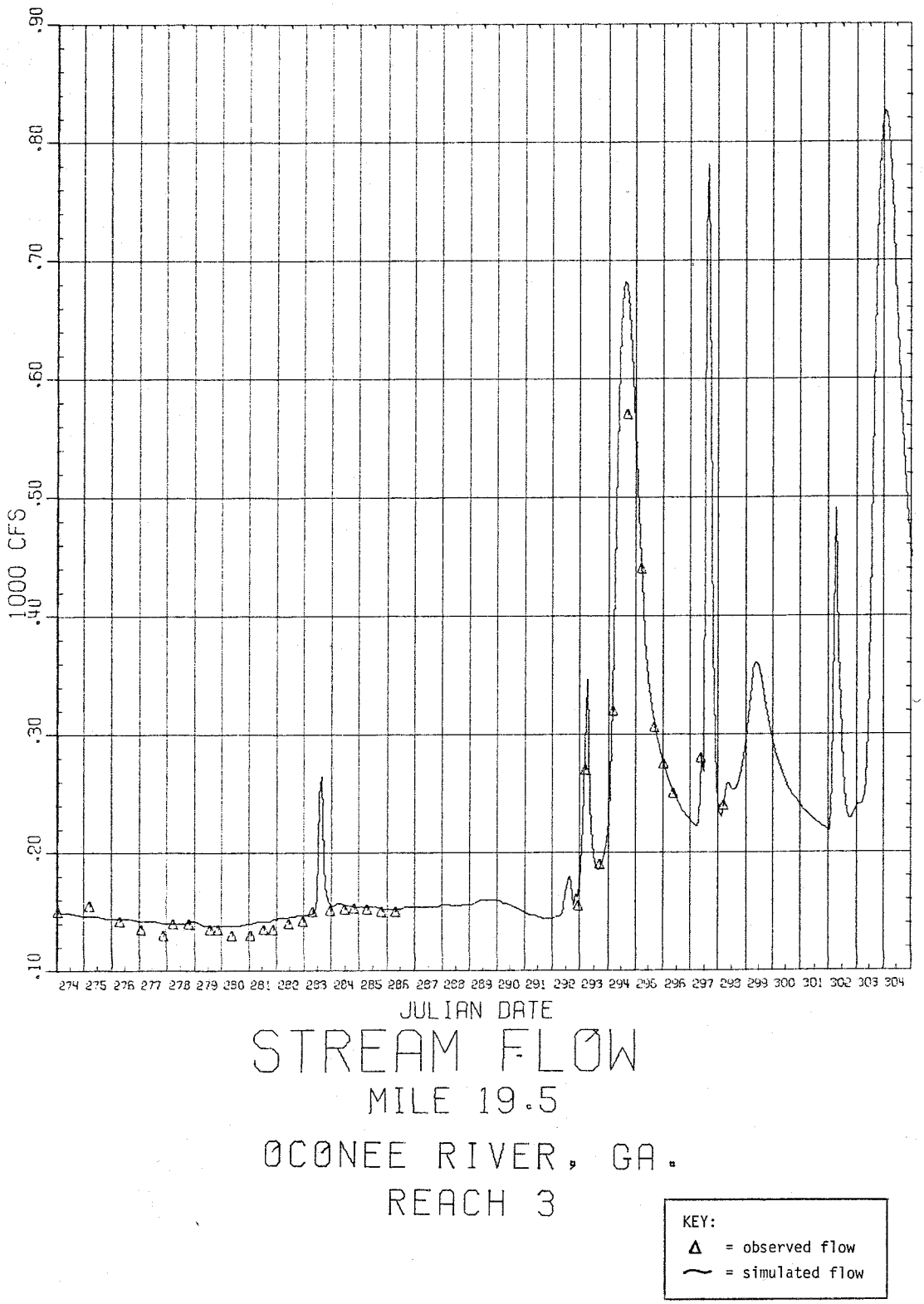


Figure II-5. Illustrative Plot of Stream Flow from Water Quality Versus Time Plotting Program

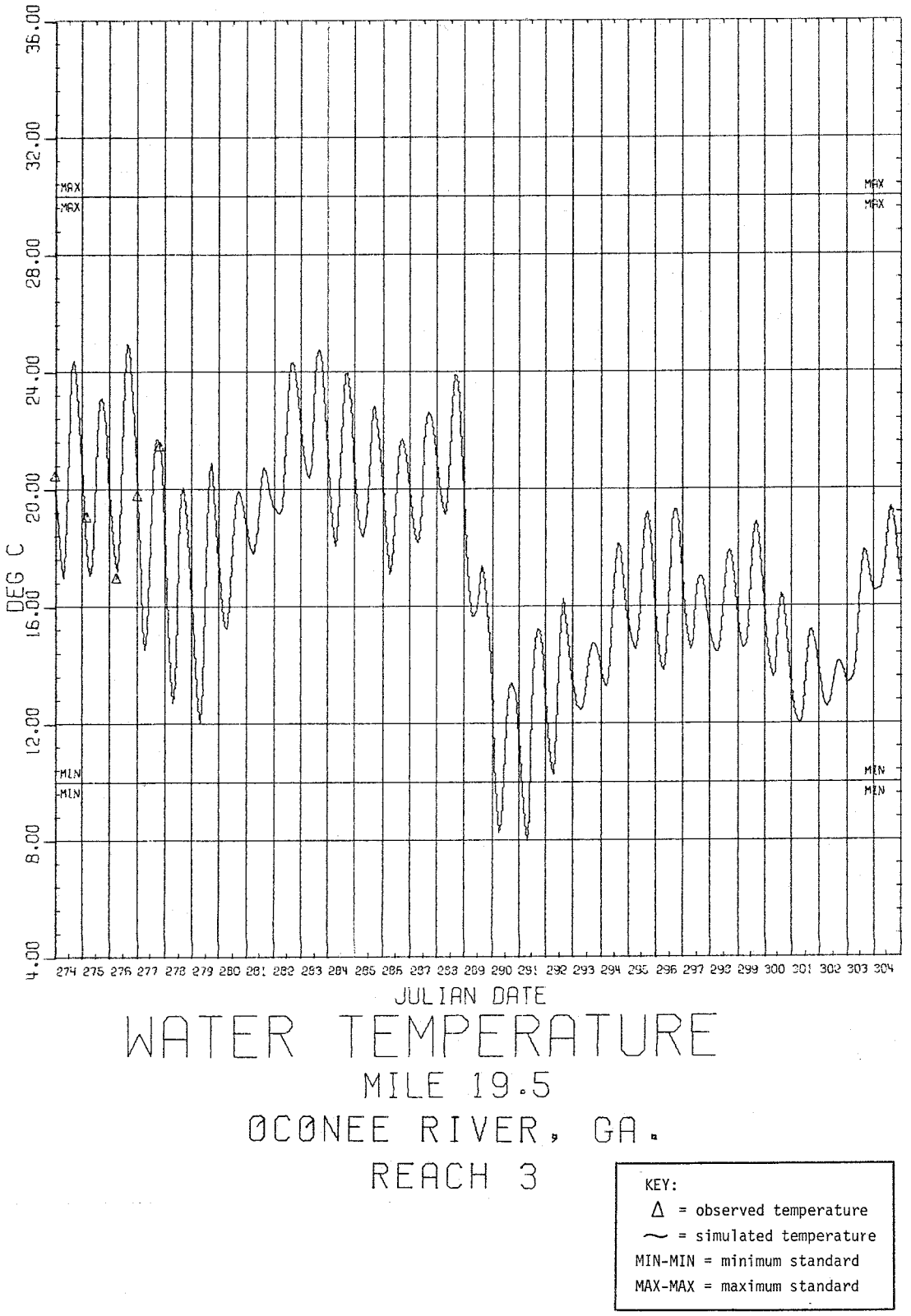


Figure II-6. Illustrative Plot of Water Temperature from Water Quality Versus Time Plotting Program

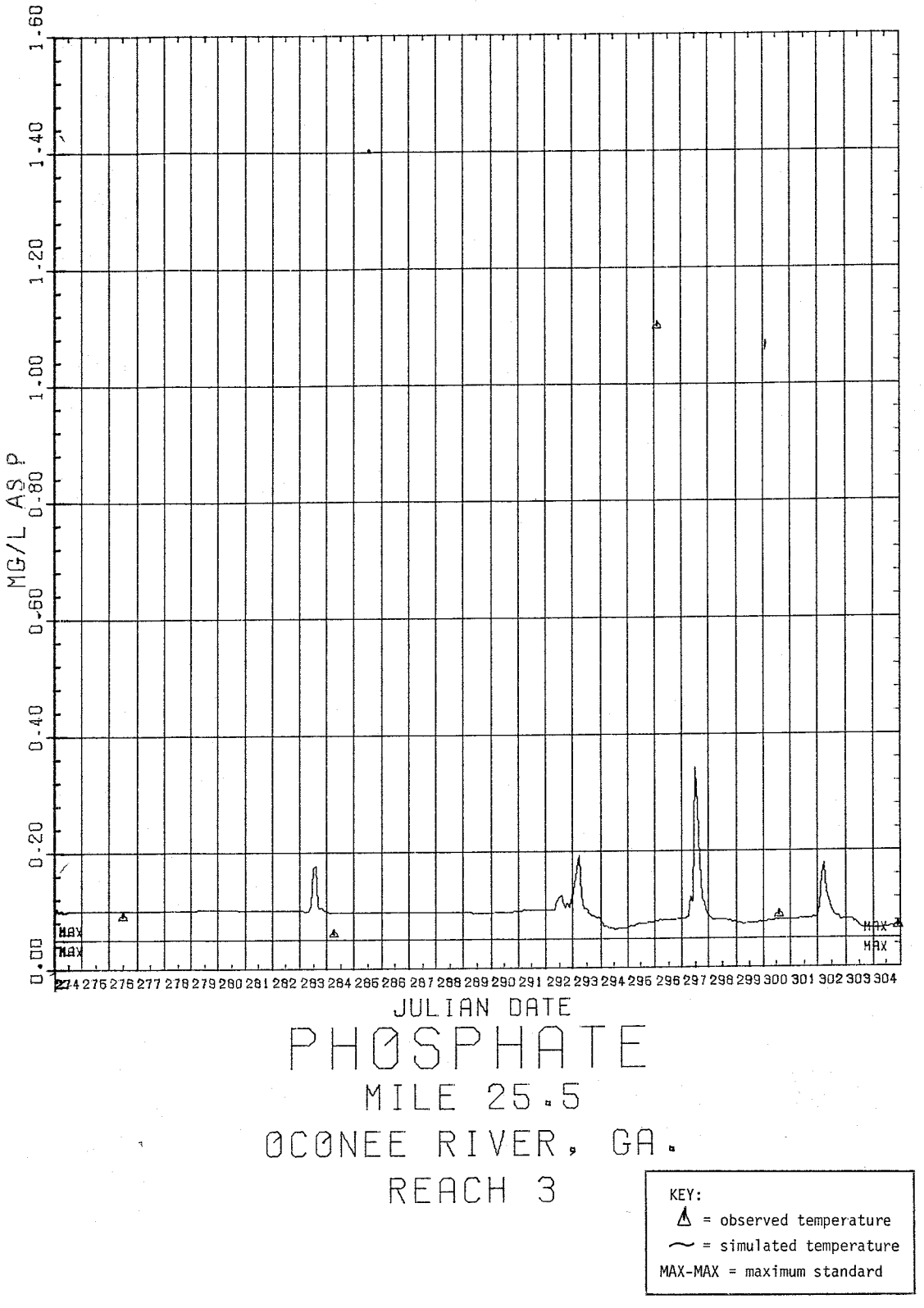


Figure II-7. Illustrative Plot of Phosphate from Water Quality Versus Time Plotting Program

bracket each Julian date, and the tick mark directly above each date denotes noon of that day. The curve of simulated results connects points spaced at two-hour intervals and the triangles are plotted at the closest two-hour interval to the time of observation.

Figure II-6, which shows water temperature, illustrates an additional capability, the inclusion of standards. Both maximum (30°C) and minimum (10°C) standards are specified and labeled.

The vertical axes of all plots are scaled to include the range of simulated results, observed data, and standards. If the observed data or standards have a range of values considerably different from the simulated results, all values are scaled onto the plot, even if the plot then lacks some resolution, as shown in Figure II-7. This plot shows one observed phosphate value of 1.1 mg/l, while the highest simulated value is approximately 0.35 mg/l. If there is reason to believe the 1.1 mg/l observation is an outlier, it can be removed from the input data, and the range of the vertical axis will then be approximately from 0.0 to 0.4 mg/l, instead of from 0.0 to 1.6 mg/l, and the plot will show more resolution.

III. STATISTICAL PROGRAM

Description of Capabilities

This component of the Stream Water Quality Post-Processor provides a statistical summary, by node within the study reach, of the output of the Stream Quality Module of the WQRRS Model. The specific capabilities of the program are described below:

1. The program computes statistics for the 11 water quality parameters (including flow) stored on the output tape of the WQRRS model which contains the results of the stream quality simulations. The parameters are analyzed in the following order and with the following units:

    - streamflow, m^3/s
    - temperature, °C
    - dissolved oxygen, mg/l
    - ammonia nitrogen, mg/l
    - nitrate nitrogen, mg/l
    - phosphate phosphorus, mg/l
    - alkalinity, mg/l as $CaCO_3$
    - log coliforms, log MPN/100 ml
    - total dissolved solids, mg/l
    - pH
    - 5-day biochemical oxygen demand, mg/l

    For these parameters the program computes the mean and standard deviation, and determines the maximum and minimum values over the period

of record. In computing the mean and standard deviation of log coliforms and pH, the program first takes the anti-logarithm of each logged value, and then computes the mean and standard deviation. The values that appear in the tabulated output for the mean and standard deviation of pH and log coliform are actually the logged values of each of these two statistics. For example, suppose a number of pH values produce a mean of 7.6 and standard deviation of 8.6. Then 7.6 ± 8.6 is <u>not</u> a true indicator of the variability of the pH, but rather the following is a true indication of the variability of the hydrogen ion concentration:

$$10^{-7.6} \pm 10^{-8.6}$$

In this case the variability of the hydrogen ion concentration is an order of magnitude less than the mean value. It should also be noted that averaging pH's is not entirely scientifically justifiable, but is done in this program to provide a <u>general</u> indication of the average concentration of hydrogen ion.

2. The time period over which analyses are performed can be identical with the study period, or it can be a shorter period, as specified by the user.

3. Any number of nodes within the study reach can be analyzed, generally (but not necessarily) beginning in the most upstream direction. Also, it is possible to analyze more than one reach sequentially. However, because of the way the program is written it is inefficient computationally to do this. It is suggested that to conserve computer time when multiple reaches are to be analyzed, each reach be written on a separate file, and analyzed separately.

4. Observed data for all parameters except flow can be compared against the simulated results at any node. The program computes the error associated with each observation (the difference between simulated and observed values), and from this difference it computes the mean error and standard deviation. The program also determines the number of observation points for each parameter (which can differ from parameter to parameter).

5. Water quality standards can be specified for up to ten parameters (stream flow not included), and the number of points exceeding these standards is computed over the study period. The percent of simulated values exceeding the standards is also calculated. Both maximum and minimum water quality standards can be specified for temperature and pH.

Description of Subroutines

The statistical program is comprised of three basic programs, as shown in Figure III-1. The program is only modularized to a minor extent, and all statistical calculations are contained in the main routine WQSTAT.

SUBROUTINE SKIP skips to the appropriate place in the file of selected data. The arguments of this subroutine are the logical unit number and the number of records to be skipped.

SUBROUTINE JULDAY converts calendar dates contained in variables that have day, month, and year information embedded in them to Julian date. The subroutine also puts the day, month, and year information contained in the calendar dates into a COMMON block.

Card Format

This section contains a detailed description of every variable on each input card. These descriptions will be found in Table III-1 which follows this discussion. Figure III-2 at the end of the section shows the sequential arrangement of input cards for this program.

All variables, except those specified on the TITLE cards, are specified by fields of eight columns each. Titles are given in A4 format. Field 1 of each card is always reserved for card identification, and must be left justified.

The range of values a variable may assume and the corresponding conditions are described below. Some variables simply indicate the program option to be used by specifying discrete numbers. For those

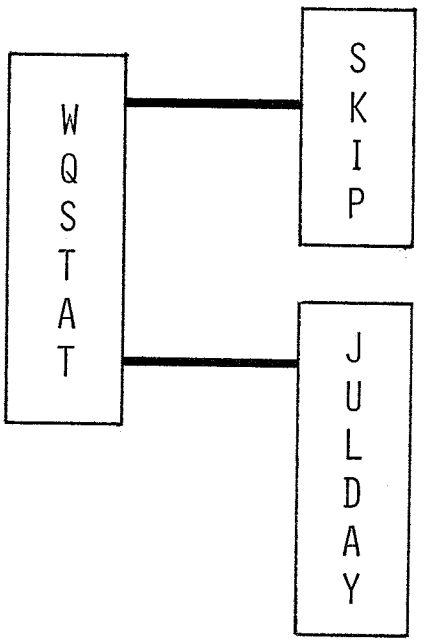


Figure III-1. Subroutines Comprising Statistical Program

variables having a + sign shown under the column "value," the numerical value of the variable is entered as input. Where the value is zero, the corresponding input field may be left blank.

Data for variables beginning with the letters I through N are integers and should not include decimals, but should be right justified in their field. Data for variables beginning with letters A through H and O through Z are floating point variables and should be right justified in their field if the decimal points are not punched. Variables containing titles may begin with any letter, and can begin in any column in their specified field.

The simulated results of the Stream Quality Module are read from tape once the required data cards have been read. A detailed understanding of how the program reads the data from the tape is not required of the user. However, the user does have to prescribe values of certain parameters stored on the tape via card input. These parameters will be discussed with the input card descriptions.

It is also of interest to the user to note that, at the time of this writing, an additional variable is being written onto the tape containing the stream water quality results that was not present on earlier tapes. This additional variable specifies the river reach, and is contained in the first field of each record on the tape. Otherwise, the information stored on the new and old tapes is identical. The effect of this is that tapes containing results that do not have a reach specification cannot be processed using this program without modifying both the tape read statement contained in this program, and the program logic that checks for the desired reach number.

TABLE III-1

DETAILED DESCRIPTIONS OF INPUT CARDS
FOR STATISTICAL PROGRAM

Title Description Card* - Three title cards are required.

Field	Variable	Value	Description
1		TITLE	Card Identification.
2	TITLE(1)	Alpha (A4)	The array TITLE is the title that will be printed on the top of each page of output. Any alphanumeric characters may be used in the title.
.	.	.	
.	.	.	
10	TITLE(18)	Alpha (A4)	

*This card and all remaining cards in this description are required cards unless the specific card description defines it as being optional.

TABLE III-1
(CONTINUED)

JOB1 Card - Designates input unit for simulation data and describes river reach and simulation period.

Field	Variable	Value	Description
1		JOB1	Card identification.
2	LP	+	Designates the input unit number from which the program will read the simulation data generated by the WQRRS program.
		0	If LP is not a positive number, the program terminates operation.
3	RMST	+	The river mile for the beginning of the reach for the simulation data on unit LP (JOB1 card, field 2).
4	RMEND	+	The river mile for the end of the reach for the simulation data on unit LP (JOB1 card, field 2).
5	RMINC	+	Subreach length in miles.
6	IDAY	+	First day of the simulation period on unit LP (JOB1 card, field 2). Enter as year, month, day (e.g., 741001).
7	LDAY	+	Last day of the simulation period on unit LP (JOB1 card, field 2). Enter as year, month, day (e.g., 741031).
8	INCHR	+	Simulation time interval in hours.

TABLE III-1
(CONTINUED)

JOB2 Card - Designates river mile where calculations are to be made and specifies time limits.

Field	Variable	Value	Description
1		JOB2	Card identification.
2	RMOBS	+	River mile at which observed or simulated values were made. If RMOBS is not specified, program returns to beginning to read new TITLE card.
3	NOBS	+	Number of observed data cards (i.e., number of pairs of OBS1 and OBS2 cards).
		0	If NOBS is zero, then no observed data cards are read.
4	IDST	+	First day of "special study period."* Enter as year, month day (e.g., 740825). If no value is entered, IDAY (JOB1 card, field 6) will be used.
5	LDST	+	Last day of "special study period."* Enter as year, month, day (e.g., 740910). If no value is entered, LDAY (JOB1 card, field 7) will be used.
6	KFC	0	Indicates that observed temperature data and temperature standards are in degrees Celsius.**
		1	Indicates that observed temperature data and temperature standards are in degrees Fahrenheit.**
7	JSTN	0	Indicates that water quality standard cards STD1 and STD2 will not follow the JOB2 card.***
		1	Indicates that water quality standard cards STD1 and STD2 will follow the JOB2 card.***

See following page for footnotes.

TABLE III-1
(CONTINUED)

JOB2 Card (Continued)

Field	Variable	Value	Description
8	JCOMP	0	Indicates that simulation data are not to be compared with water quality standards.
		1	Indicates that simulation data are to be compared with water quality standards. JCOMP should not be set equal to 1 unless water quality standards have been or will be read by the program
9	KREACH	+	Reach number identifying the study reach.
10	JMNMX	+	Index requesting output on water quality concentrations vs. % of time of exceedance. These values are used to plot quality duration curves.
		0	Output as documented.

*Special study period is defined as that portion of the simulation period on unit LP (JOB1 card, field 2) which is of interest for statistical summary purposes. If IDST, (JOB2 card, field 4) and LDST (JOB2 card, field 5) are equal, the special study period is one day.

**The program performs all temperature calculations in degrees Celsius. Hence, even if observed temperatures are input in degrees Fahrenheit, they will be converted to degrees Celsius before any computations are performed. Simulated temperature data are in degrees Celsius.

***The water quality standards cards STD1 and STD2 need not be read more than once unless water quality standards change at a new river mile. When standards are not reread set JSTN=0. Otherwise, set JSTN=1 and include the STD1 and STD2 cards.

TABLE III-1
(CONTINUED)

MIN Cards

Field	Variable	Value	Description
1		MIN1	Card identification.
2-10	MMIN	+	The minimum simulated value expected for each of the first 9 water quality parameters. The field may be left blank for any parameter not being simulated.

Field	Variable	Value	Description
1		MIN2	Card identification.
2	MMIN	+	The minimum simulated value expected for the tenth water quality parameter. The field may be left blank if the parameter is not being simulated.

MAX Cards

Field	Variable	Value	Description
1		MAX1	Card identification.
2-10	MMAX	+	The maximum simulated value expected for each of the first 9 water quality parameters. The field may be left blank for any parameter not being simulated.

Field	Variable	Value	Description
1		MAX2	Card identification
2	MMAX	+	The maximum simulated value expected for the tenth water quality parameter. The field may be left blank if the parameter is not being simulated.

TABLE III-1
(CONTINUED)

STD1 Card* - Include only if JSTN (JOB2 card, field 7) is equal to 1. If it is not, skip to the OBS1 card.

Field	Variable	Value	Description
1		STD1	Card identification.
2	STAN(1)	+	Standard for minimum water temperature in degrees Celsius or Fahrenheit as indicated by the value of KFC (JOB2 card, field 6).**
3	STAN(2)	+	Standard for maximum water temperature in degrees Celsius or Fahrenheit as indicated by the value of KFC (JOB2 card, field 6).**
4	STAN(3)	+	Standard for minimum dissolved oxygen in mg/l.
5	STAN(4)	+	Standard for maximum ammonia nitrogen in mg/l.
6	STAN(5)	+	Standard for maximum nitrate nitrogen in mg/l.
7	STAN(6)	+	Standard for maximum phosphate phosphorus in mg/l.
8	STAN(7)	+	Standard for maximum alkalinity in mg/l.
9	STAN(8)	+	Standard for maximum coliform in MPN/100 ml.
10	STAN(9)	+	Standard for maximum total dissolved solids in mg/l.

*Standards values need to always be specified for all 12 STAN values on the STD1 and STD2 cards. If no comparison is to be made between the standards and the simulated values, the appropriate STAN field is left blank.

**If observed temperature values are read in as degrees Fahrenheit, then STAN(1) and STAN(2) should be in degrees Fahrenheit. Otherwise, they should be in degrees Celsius.

TABLE III-1
(CONTINUED)

STD2 Card* - Include only if JSTN (JOB2 card, field 7) is equal to 1. If it is not, skip to the OBS1 card.

Field	Variable	Value	Description
1		STD2	Card identification.
2	STAN(10)	+	Standard for minimum pH.
3	STAN(11)	+	Standard for maximum pH.
4	STAN(12)	+	Standard for maximum 5-day carbonaceous BOD in mg/l.

*See the first footnote at the bottom of the STD1 card.

TABLE III-1
(CONTINUED)

OBS1 Card*- Include only if NOBS (JOB2 card, field 3) ≠ 0.

Field	Variable	Value	Description
1		OBS1	Card identification.
2	NDOB	+	Calendar day of observation. Enter as year, month, day (e.g., 740805).
3	NHROB	+	The hour the observation was made. Enter as a 4 digit number from 0100 to 2400. If no hour is entered, the program will compute the error as the difference between the observed value and the maximum or minimum simulated value for the day using whichever error is smaller.**
4	XOBS(1)	+	Water temperature in degrees Celsius or Fahrenheit depending on the value of KFC (JOB2 card, field 6).
5	XOBS(2)	+	Dissolved oxygen in mg/l.
6	XOBS(3)	+	Ammonia nitrogen in mg/l.
7	XOBS(4)	+	Nitrate nitrogen in mg/l.
8	XOBS(5)	+	Phosphate phosphorus in mg/l.
9	XOBS(6)	+	Alkalinity as calcium carbonate in mg/l.
10	XOBS(7)	+	Coliform in MPN/100 ml.

*There must be one pair of OBS1 and OBS2 cards for each observation. Each pair should be placed in chronological order. Any pair with NHROB (OBS1 card, field 3) not given should be placed after all other observation cards for the same day. If no observed value is to be specified for a particular field, that field is left blank. If the observed value is a true zero, a small positive value should be entered instead.

**If NHROB (OBS1 card, field 3) is no more than an hour different from a time for which simulated data are stored on tape, the data taken at this time will be compared to the simulated data at the closest hour.

TABLE III-1
(CONTINUED)

OBS2 Card - Include only if NOBS (JOB2 card, field 3) ≠ 0.

Field	Variable	Value	Description
1		OBS2	Card identification.
2	XOBS(8)	+	Total dissolved solids in mg/l.
3	XOBS(9)	+	pH.
4	XOBS(10)	+	5-day carbonaceous BOD in mg/l.

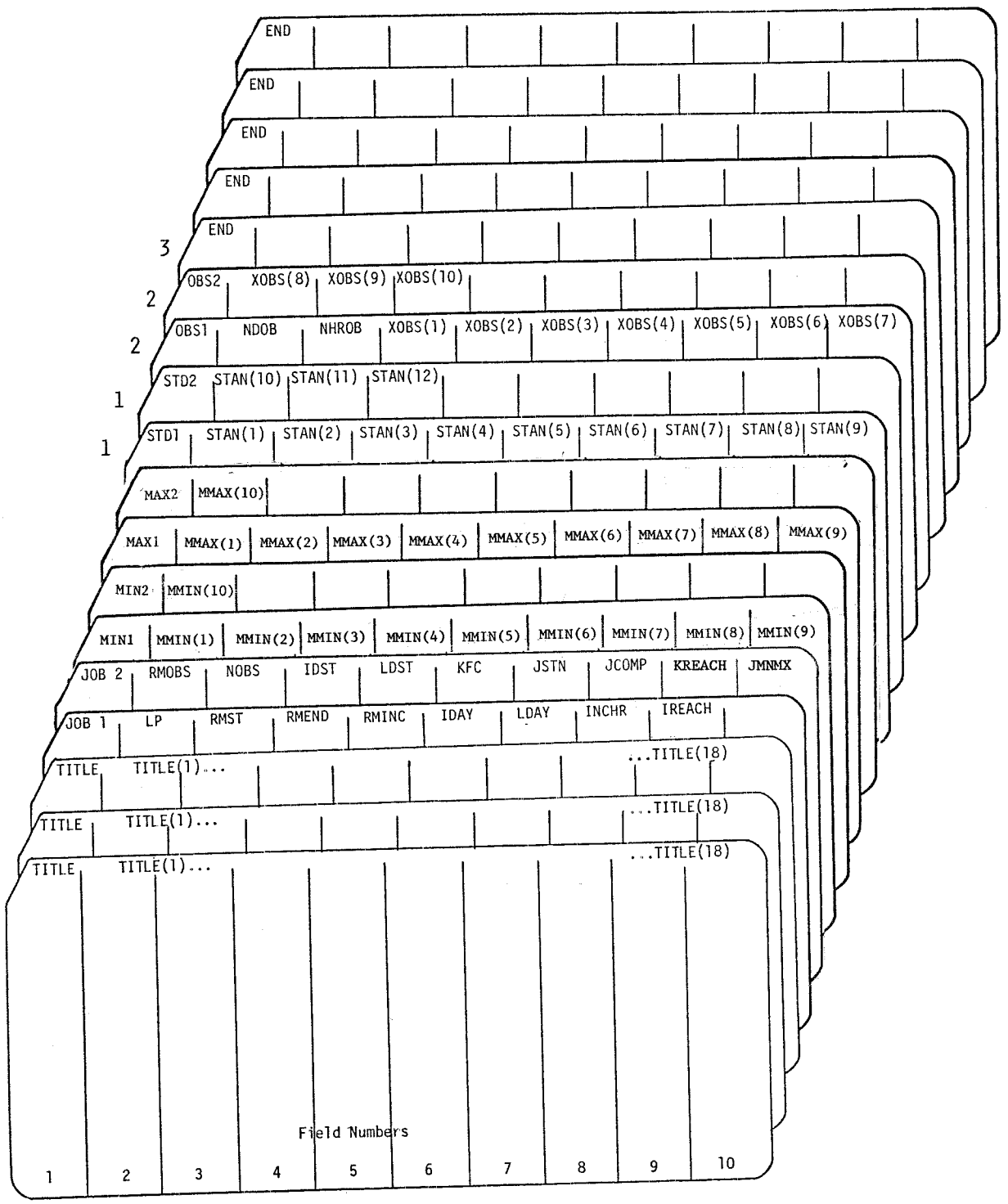
TABLE III-1
(CONTINUED)

NOTE: If another river mile is to be analyzed, another JOB2 card is to follow the OBS2 card, which is then followed by the STD and OBS cards. This sequence is repeated for each new river mile to be analyzed before the card sequence is ended by 5 END cards.

END Description Card*

Field	Variable	Value	Description
1		END	Card identification.

*If a single reach is being analyzed, five END cards are needed as the last input cards. If another reach, stored on the same file, is to be analyzed, only one END card is used, followed by the repetition of the entire card stream, beginning with the three TITLE cards.



NOTE 1. STD1 and STD2 cards are required only if standards are to be read.

NOTE 2. These are NOBS (JOB2 card, field 3) pairs of OBS1 and OBS2 cards.

NOTE 3. If another river mile is to be analyzed, another JOB2 card is to follow the OBS2 card, which is then followed by the STD and OBS cards. This sequence is repeated for each new river mile to be analyzed before the card sequence is ended by 5 END cards.

Figure III-2. Sequential Arrangement of Input Cards for Statistical Program

Application of Statistical Program

The statistical program has been applied to reach 3 of the Middle Oconee River (river mile 31.5 to 17.0) near Athens, Georgia, using simulated results obtained during a study of the river from 1 October 1970 through 31 October 1970. The observed data that are used for this test case are hypothetical and are used to illustrate the program's capabilities.

Input

Figure III-3 shows the arrangement of the input data chosen for this system. The TITLE cards identify the river system under study. The JOB1 card indicates that the input unit number containing the simulated data is number 20. The remainder of the information on the JOB1 card deals with the study reach and study period. The study reach is from river mile 31.5 to river mile 17.0, and the subreaches are of length 0.5 miles. The study period spans the month of October, 1970. The simulation time interval is two hours, and the study reach is designated reach number 3.

The JOB2 card designates the river mile of the node where statistics are to be generated and specifies the time period to be included in the analysis. For each river mile where statistics are to be computed, the JOB2 card begins the set of data for that node.

The first JOB2 card in the case shown in Figure III-3 is for river mile 31.5, at which there are 11 observations. The entire study period (the month of October) is chosen as the period for which statistics will be computed, as evidenced by the variables IDST and LDST being specified by blanks. The remaining three

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQSTAT DATE

REQUESTED BY R.G. WILLEY PREPARED BY CHECKED BY PAGE 1 OF 3

	1	2	3	4	5	6	7	8	9	10
TITLE	OCONEE RIVER, GA., REACH 3									
TITLE										
TITLE										
JOB1	20	31.5	17.0	.5	701001	701031	2	3		
JOB2	31.5	1				0	1	1		
RM 31.5 STD1	10.0	30.0	5.0	.5	.5	.05	150.0	2400.0	500.0	
STD2	5.5	9.0	5.0							
OBS1	701001	01.00	19.0	8.5	.09	.55	.05	26.1	920.0	
OBS2	1.10.0	7.5	.59							
OBS1	701002	0400	18.5	8.2	.08	.50	.05	26.0	1600.0	
OBS2	1.10.0	7.0	.40							
OBS1	701004	1200	17.0	8.1	.08	0.55	.06	25.5	920.0	
OBS2		7.3	.35							
OBS1	701007	2100	17.5	8.1	.09	.59	.05	26.0	2400.0	
OBS2		7.0	0.31							
OBS1	701016	1700	14.0			.55	.06	25.1		
OBS2		7.5	0.35							
RM 31.5 OBS1	701016	1900		8.0	.09				2400.0	
OBS2										
OBS1	701020	0800			.10	.50			920.0	
OBS2										
OBS1	701023	0300			.09	.65			920.0	
OBS2										
OBS1	701026	2400			.14	.66			920.0	
OBS2										
OBS1	701030	0500			.15	.58			920.0	
OBS2										
OBS1	701031	2400			.11	.55			920.0	
OBS2										
JOB2	29.0	5			0	1	1			

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Figure III-3. Coding Sheets Showing Sample Input Data for the Statistical Program

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM

REQUESTED BY R.C. WILLEY PREPARED BY CHECKED BY DATE PAGE 2 OF 3

	1	2	3	4	5	6	7	8	9	10
RM 29.0	STD1	10.0	30.0	5.0	0.5	0.5	0.05	150.0	2400.0	500.0
	STD2	5.5	9.0	5.0						
	OBS1	70.1001	0400	18.0	9.5					920.0
	OBS2			0.30						
	OBS1	70.1008	2100	18.5	9.6					1600.0
	OBS2			0.31						
RM 29.0	OBS1	70.1018	0700	11.0	10.1					1600.0
	OBS2			0.25						
	OBS1	70.1027	1600	13.5	9.0					920.0
	OBS2			0.28						
	OBS1	70.1031	1600	17.5	8.5					
	OBS2			0.10						
	JOB2	25.5	5			0				
RM 25.5	STD1	10.0	30.0	5.0	0.5	0.5	0.05	150.0	2400.0	500.0
	STD2	5.5	9.0	5.0						
	OBS1	70.1003	1200	24.0	8.5			0.09		
	OBS2	90.0								
	OBS1	70.1011	1200	18.0	9.0			0.06		
	OBS2	90.0								
RM 25.5	OBS1	70.1013	0300	14.1	9.3			1.10		
	OBS2	110.0								
	OBS1	70.1027	1500		10.1			0.09		
	OBS2	105.0								
	OBS1	70.1031	2300		8.5			0.07		
	OBS2									
	JOB2	19.5	5			0				
RM 19.5	STD1	10.0	30.0	5.0	0.5	0.5	0.05	150.0	2400.0	500.0
	STD2	5.5	9.0	5.0						
RM 19.5	OBS1	70.1001	0100	20.5	8.5	0.08	0.25	0.09	25.0	1600.0
	OBS2	100.0	7.5	0.5						

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Figure III-3 (Continued)

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM | DATE

REQUESTED BY R.G. WILLEY | PREPARED BY | CHECKED BY | PAGE 3 OF 3

	1	2	3	4	5	6	7	8	9	10
RM 19.5	OBS1	7Ø1ØØ2	Ø4ØØ	19.1	9.Ø	Ø.14	Ø.65	Ø.14	24.Ø	92Ø.Ø
	OBS2	11Ø.Ø	7.6	1.3						
	OBS1	7Ø1ØØ3	Ø7ØØ	17.Ø	9.6	Ø.15	Ø.65	Ø.14	25.1	92Ø.Ø
	OBS2	11Ø.Ø	7.7	1.2						
	OBS1	7Ø1ØØ3	24ØØ	19.8	9.Ø	Ø.16	Ø.66	Ø.13	29.Ø	92Ø.Ø
	OBS2	1ØØ.Ø	7.7	1.3						
	OBS1	7Ø1ØØ4	21ØØ	21.5	8.5	Ø.17	Ø.69	Ø.13	26.Ø	24ØØ.Ø
	OBS2	105.Ø	7.5	1.2						
	JOB2	17.Ø	1			Ø				
RM 17.0	STD1	1Ø.Ø	3Ø.Ø	5.Ø	Ø.5	Ø.5	Ø.Ø5	15Ø.Ø	24ØØ.Ø	5ØØ.Ø
	STD2	5.5	9.Ø	5.Ø						
RM 17.0	OBS1	7Ø1Ø31	24ØØ	17.Ø	8.5	Ø.1Ø	Ø.65	Ø.2Ø	24.Ø	92Ø.Ø
	OBS2	1ØØ.Ø	7.3	Ø.4Ø						
	END									
	END									
	END									
	END									
	END									

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Figure III-3 (Continued)

variables of the JOB2 card are dichotomous, each having values of 0 or 1. In this example, KFC has the value of 0, indicating that the observed temperature is in degrees Celsius. JSTN equals 1, indicating that water quality standard cards will follow the JOB2 card, and JCOMP is also 1 indicating that simulated data will be compared with the water quality standards.

Since JSTN has the value of 1, the STD1 and STD2 cards containing specified water quality standards follow the JOB2 card. In this example, standards for all ten water quality parameters are specified, since there are no blank fields.

Pairs of OBS1 and OBS2 cards follow the STD2 card, the number of pairs being equal to NOBS, defined in field 3 of the JOB2 card. The OBS1 card contains the date (NDOB) and military time in hours (NHROB) of the observation, as well as the observed values for the first seven parameters (not including flow). The OBS2 card contains the remaining three parameters. When no observed data were taken for a particular parameter, that field is left blank.

Additional JOB2 cards follow the last OBS2 card of a particular data sequence (for a particular location) when the statistics at other locations are desired. For this test case there are five JOB2 cards, indicating statistics are computed at river miles 31.5, 29.0, 25.5, 19.5, and 17.0.

The STD1 and STD2 cards and pairs of OBS1 and OBS2 cards follow each additional JOB2 card. Since the standards are the same at all five locations, the last four pairs of STD1 and STD2 cards could have been omitted if JSTN (field 7, JOB2 card) had been set to zero for

the last four JOB2 cards. When, finally, no more analyses are to be done the card sequence is ended by five END cards.

Output

Figure III-4 illustrates the output of the program at river mile 25.5. The title from the three TITLE cards is printed at the top left-hand corner, in this case namely "OCONEE RIVER, GA., REACH 3." Then a summary of the input data is generated that contains reach information, study period information, and the location where the observed data were measured. The first table below this information is both a summary of the simulated values and a comparison between the simulated and observed values. Prior to printing this table, the number of simulation points at this river mile is shown (373 = 12 per day times 31 days, except the first day has 13 points).

The last table in Figure III-4 shows the selected water quality standards for all the parameters. Any number of water quality parameters can be omitted from this table by leaving the appropriate standard blank on the STD1 or STD2 card. This table also shows the number of simulated points exceeding the standard, and the percent of points exceeding the standards. "Exceeding the standard" means a value higher than the standard when the standard is a maximum (as 0.5 mg/l is for ammonia nitrogen) and means a value lower than the standard for a minimum standard (as 5.0 mg/l is for dissolved oxygen).

OCONEE RIVER, GA., REACH 3

********** INPUT DATA **********

BEGINNING OF REACH RIVER MILE	31.50	
END OF REACH RIVER MILE	17.00	
SUBREACH LENGTH (MILES)	.50	
COMPUTATION INTERVAL (HOURS)	2	
FIRST DAY OF SIMULATION PERIOD	274	(1 OCT 70)
LAST DAY OF SIMULATION PERIOD	304	(31 OCT 70)
NUMBER OF DAYS IN SIMULATION PERIOD	31	
OBSERVATIONS AT RIVER MILE	25.50	
FIRST DAY OF STUDY PERIOD	274	(1 OCT 70)
LAST DAY OF STUDY PERIOD	304	(31 OCT 70)
NUMBER OF DAYS IN STUDY PERIOD	31	

****

WATER QUALITY PARAMETERS AT RIVER MILE 25.50
NUMBER OF SIMULATION POINTS 373

PARAMETER	SIMULATION VALUES MINIMUM	MAXIMUM	MEAN	STD.DEV.	ERROR (SIMULATED-OBS.) MEAN	STD.DEV.	NO. OF OBSERVED VALUES
FLOW(M**3/S)	3.1	22.6	5.5	3.9			
TEMP(DEGREE C)	7.2	26.0	17.1	3.7	1.3	2.2	3
OXY (MG/L)	8.0	11.3	9.4	.6	.1	.4	5
NH3 (MG/L AS N)	.091	.275	.124	.014	.000	.000	0
NO3 (MG/L AS N)	.437	.993	.623	.028	.000	.000	0
PO4 (MG/L AS P)	.066	.343	.095	.023	-.193	.453	5
ALKA(MG/L AS CACO3)	25.0	25.0	25.0	.0	.0	.0	0
LOG COLI(LOG MPN/100ML)	2.95	4.49	3.25	3.52	.00	.00	0
TDS (MG/L)	100.	100.	100.	0.	1.	10.	4
PH	7.5	7.7	7.6	8.6	.0	.0	0
BOD (MG/L)	.4	3.2	.7	.2	.0	.0	0

****

PARAMETER	WATER QUALITY STANDARD	POINTS EXCEEDING STANDARD NUMBER	PERCENT
TEMP(DEGREE C)	10.0 MIN.	9	2.41
TEMP(DEGREE C)	30.0 MAX.	0	.00
OXY (MG/L)	5.0 MIN.	0	.00
NH3 (MG/L AS N)	.500 MAX.	0	.00
NO3 (MG/L AS N)	.500 MAX.	372	99.73
PO4 (MG/L AS P)	.050 MAX.	373	100.00
ALKA(MG/L AS CACO3)	150.0 MAX.	0	.00
LOG COLI(LOG MPN/100ML)	3.38 MAX.	36	9.65
TDS (MG/L)	500. MAX.	0	.00
PH	5.5 MIN.	0	.00
PH	9.0 MAX.	0	.00
BOD (MG/L)	5.0 MAX.	0	.00

Figure III-4. Illustrative Output of the Statistical Program

IV. WATER QUALITY VERSUS DISTANCE PLOTTING PROGRAM

Description of Capabilities

This component of the post-processor plots critical values of water quality parameters throughout the study reach for the period of study. A summary of the program's capabilities follows. These capabilities will later be illustrated by an application of the program to a test case.

The capabilities of this plotting program are given below:

1. The program plots the maximum and/or minimum values for up to 11 water quality parameters (including flow) at each location in the study reach over the period of study for the simulated results that are stored on the output tape from the WQRRS model. The parameters normally are contained on tape in the following order, and are plotted with the units indicated:

    - streamflow, 1000's cfs
    - water temperature, °C
    - dissolved oxygen, mg/l
    - ammonia nitrogen, mg-N/l
    - nitrate nitrogen, mg-N/l
    - phosphate phosphorus, mg-P/l
    - alkalinity, mg/l as $CaCO_3$
    - log coliform, log MPN/100 ml
    - total dissolved solids, mg/l
    - pH
    - 5-day biochemical oxygen demand, mg/l

2. Maximum and/or minimum standards values can be included on the plots with the simulated data. These standards can be chosen to be step functions that vary by river mile, to reflect changing water quality designations. The step function for each standard may assume up to ten distinct values.

3. Observed data can be included on the plots. These data points should be the maximum and/or minimum observed values at the river mile they were measured. Up to 50 maximum and 50 minimum observed values each can be plotted. The sum of these first three capabilities comprise what will be later referred to as a Type 1 plot.

4. A second type of plot (which will be called a Type 2 plot) can be generated that shows only unconnected points at selected river miles. The input information for these plots generally comes from the output of the statistical program (see Figure III-4) for the river miles selected for plotting. These plots contain the maximum and/or minimum simulated value(s) for the parameters being plotted for each river mile specified. They also show the mean error associated with each extreme value (mean of the simulated values minus the observed values) and the standard deviation associated with this mean error. The envelope between the points defined by including the mean error with the extreme simulated value and those defined by including both the mean error and standard deviation with the extreme simulated

value can be thought of as a maximum or minimum "normally expected" stream water quality profile.

5. For each execution of the program, exactly one reach can be analyzed. If more than one reach is to be analyzed, then sequential program runs must be made.

6. Because of variations of Cal-Comp software between computer installations, several of the subroutines comprising the program contain cards that are installation-dependent. These subroutines are: INITPL, NEXTFR, and STOPPL. Their functions are described in the next section. The program code contains comment cards indicating what these subroutines should do and that they are system-dependent. Additionally the calls to SUBROUTINE AXIS in the two main programs (WQPROF and MAIN2) may vary in the number of arguments from one installation to another. In testing this program it was found that the first eight arguments were the same at both installations used. If a ninth argument is specified which defines the number of 90° rotations to be performed before drawing the axis, this integer argument should be set to zero.

Description of Subroutines

Figure IV-1 shows the subroutines comprising this plotting program and depicts their interrelationships. PROGRAM WQPROF is the main program and reads the title to be used on every plot, the reach number and the plot option specified by the user. When plot Type 1

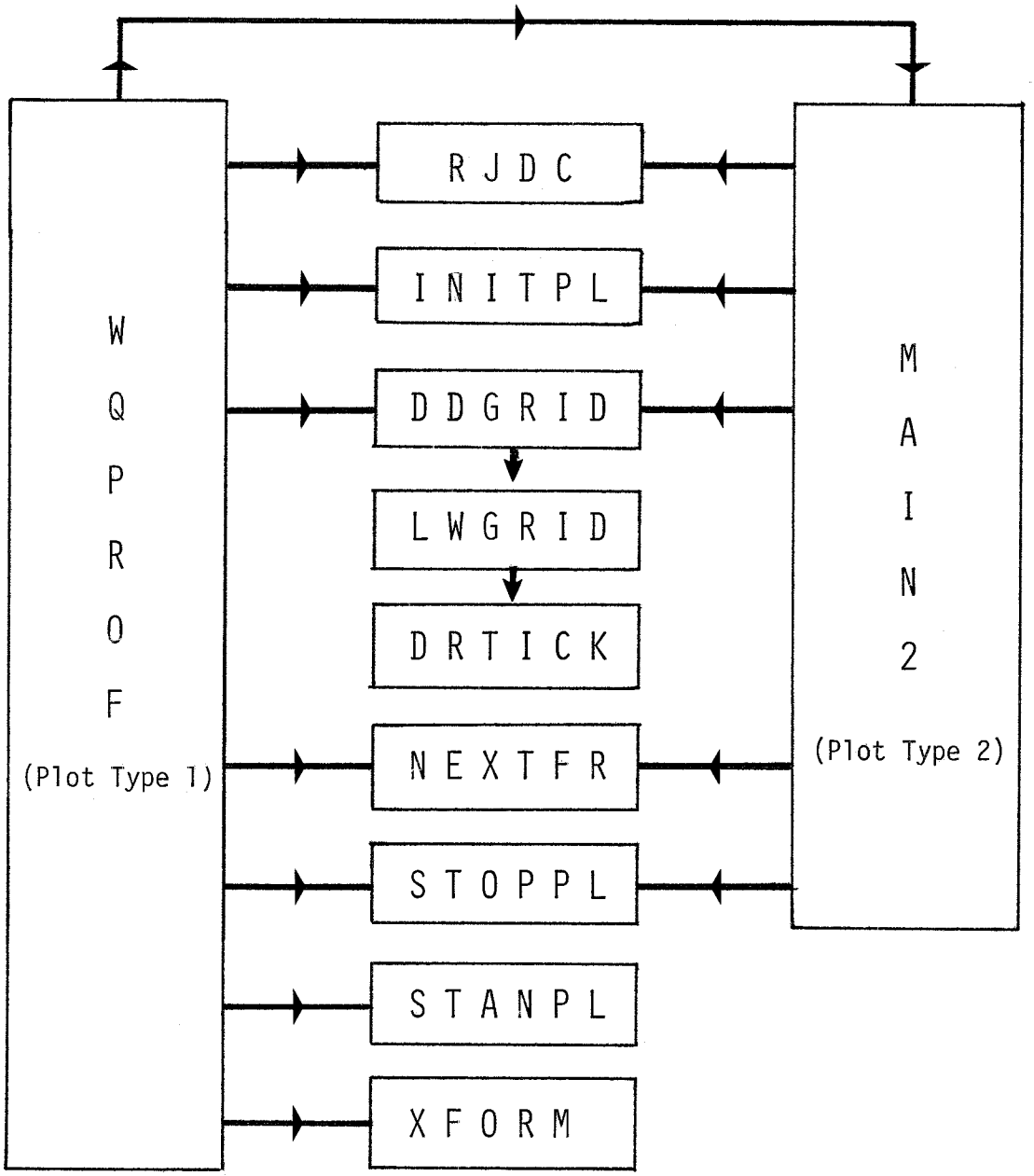


Figure IV-1. Subroutines Comprising the Water Quality Profile Plotting Program

is chosen, control remains with WQPROF, while when plot Type 2 is to be drawn PROGRAM MAIN2 becomes the main program. MAIN2 shares a large common block with WQPROF in order to conserve core usage, and is a main program in itself in that it does everything necessary to plot simulated data points.

SUBROUTINE STANPL is called by WQPROF to plot standards as step functions. It is called up to twice for each parameter, once for the maximum standard and once for the minimum standard (if both are specified). Up to ten maximum and ten minimum standards values can be specified for each parameter. If plot Type 2 only is specified by the user or no standards are to be plotted, STANPL is not called.

SUBROUTINE XFORM performs any necessary transformations on simulated data, such as conversion of flow units, when plot Type 1 is specified. Otherwise it is not called.

SUBROUTINE NEXTFR advances the plotter to the next frame at the completion of a plot. It is a separate subroutine because some of its code is installation-dependent.

The remaining subroutines are identical to subroutines contained in the first plotting program, WQPLOT, but will be described here for completeness. SUBROUTINE RJDC packs one array of hollerith characters in nA1 format into another array in which each computer word contains as many characters as the computer word size allows (4 or 6, for example). This routine removes leading and trailing blanks from the hollerith constants, and it also returns the number of non-blank characters found (imbedded blanks in a string are counted as non-blank).

SUBROUTINE INITPL initializes the plotting device. It is a separate subroutine because portions of its code can vary from installation to installation.

SUBROUTINE DDGRID draws the grid lines and tick marks used for each plot. It calls LWGRID four times (once each for the lower horizontal axis, the upper horizontal axis, the left vertical axis, and the right vertical axis).

SUBROUTINE LWGRID draws grid lines and tick marks along one axis by repeatedly calling DRTICK.

SUBROUTINE DRTICK moves the plotter pen one increment of distance along a given axis and then draws a line of specified length perpendicular to that axis. This line could be either a tick mark or a grid line.

SUBROUTINE STOPPL terminates all plotting activity. It is a separate routine because the code can vary from installation to installation.

Card Format

This section contains a detailed description of every variable on each input card. These descriptions will be found in Table IV-1 which follows this discussion. Figure IV-2 at the end of the section shows the sequential arrangement of input cards for this plotting routine.

All variables, except those used to specify titles, are specified by fields of eight columns each. Titles are given in nA1

format. Field 1 of each card is always reserved for card identification, and must be left justified.

The range of values a variable may assume and the corresponding interpretations are described below. Some variables simply indicate the program option to be used by specifying discrete numbers. For those variables having a + sign shown under the column "value," the numerical value of the variable is entered as input. Where the value is shown as zero, the corresponding input card field may be left blank.

Data for variables beginning with the letters I through N are integers and should not include decimals, but should be right justified in their field. Data for variables beginning with letters A through H and O through Z are floating point variables and should be right justified in their field if the decimal points are not punched. Variable names for titles may begin with any letter, and can begin in any column within their specified fields.

The simulated results of the Stream Quality Module are read from tape once the required data cards have been read. A detailed understanding of how the program reads data from the tape is not required of the user. However, the user does have to specify on certain of the input cards information that enables the program to extract the desired information from the tape, such as the order the parameters are stored on the WQRRS output tape (see p. IV-1).

It is also of interest to the user to note that, at the time of this writing, an additional variable is being written onto the tape containing the stream water quality results that is not present on earlier tapes. This additional variable specifies the river

reach, and is contained in the first field of each record on the tape. Otherwise, the information stored on the new and old tapes is identical. The effect of this is that tapes containing results that do not have a reach specification cannot be processed using this program without modifying both the tape read statement contained in this program, and the program logic that checks for the desired reach number.

TABLE IV-1

DETAILED DESCRIPTIONS OF INPUT CARDS FOR
WATER QUALITY VERSUS DISTANCE PLOTTING PROGRAM

Title Description Card*

Field	Variable	Value	Description
1		TITLE	Card identification.
2-4	TIT1(1) to TIT1(20)**	alpha(A1)	TIT1 and TIT2 comprise the plot title for all frames in a run. They identify the river system and reach being studied.
4-6	TIT2(1) to TIT2(20)**	alpha(A1)	

*This card and all remaining cards in this decription are required cards unless the specific card description defines it as being optional.

**TIT1 ends in field 4, and TIT2 begins in field 4.

Option Card

Field	Variable	Value	Description
1		OPTION	Card identification.
2	NOPT	0	Specifies plot Type 1 only.
		1	Specifies plot Type 2 only.
		2	Specifies plot Type 1 and Type 2 only.
3	IREACH	+	Specifies reach number of the study reach.

TABLE IV-1
(CONTINUED)

Job Card 1 - The following sequence of cards, from this JOB1 card through the MNOBS card are included only if NOPT (OPTION card, field 2) = 0 or 2. If NOPT=1, skip to the JOBA card.

Field	Variable	Value	Description
1		JOB1	Card identification.
2	NPAR	+	Number of parameters to be plotted.
3	MAXMIN	0	Plots containing minimum critical values only will be generated.
		1	Plots containing maximum critical values only will be generated.
		2	Plots containing both minimum and maximum critical values will be generated.
4	NUMDY	+	Number of days of data on tape.
5	NHHI	+	Number of hours between stored simulated data points.
6	NS	+	Number of nodes in the study reach.
7	NPTAPE	+	Number of parameters stored on tape.
8	INTP	+	Logical unit number of simulated data file.

TABLE IV-1
(CONTINUED)

Job Card 1 (Continued)

Field	Variable	Value	Description
9	IFLOW	0	Equals 0 if observed flow data are in cfs.*
		1	Equals 1 if observed flow data are in m^3/s.*
10	CLNGTH	+	Length of horizontal axis in inches.**

*If there are no observed flow data IFLOW can be of any integer value.

**CLNGTH will be made longer than specified by the user, if necessary, to keep the plot legible.

TABLE IV-1
(CONTINUED)

Job Card 2* - Include only if NOPT (OPTION card, field 2) = 0 or 2. If NOPT=1, skip to the JOBA card.

Field	Variable	Value	Description
1		JOB2	Card identification.
2	IPAR(I)	+	Order of each parameter on tape for which a plot is to be generated (see p. IV-1).**
3	PSCAL(I,1)	+	Minimum value of the IPAR parameter on the Y axis.
4	PSCAL(I,2)	+	Maximum value of the IPAR parameter on the Y axis.
5-10	IPDAY(I,1-6)	+	Julian day for plotting profiles other than maximum or minimum. (Up to 6 extra plots).

*There are NPAR (JOB1 card, field 2) JOB2 cards.

**For example, if the first plot is to be generated for the third parameter stored on tape, then IPAR(1)=3.

Job Card 3* - Include only if NOPT (OPTION card, field 2) = 0 or 2. If NOPT=1, skip to the JOBA card.

Field	Variable	Value	Description
1		JOB3	Card identification.
2-4	GRLBLE(1,I)... GRLBLE(20,I)**	alpha(A1)	A 20 character title for the horizontal axis for parameter I.
4-6	YLBUL(1,I)... YLBUL(15,I)**	alpha(A1)	A 15 character title for the vertical axis for parameter I.

*There are NPAR (JOB1 card, field 2) JOB3 cards.

**GRLBLE ends in field 4, and YLBUL begins in field 4.

TABLE IV-1
(CONTINUED)

Job Card 4* - Include only if NOPT (OPTION card, field 2) = 0 or 2. If NOPT=1, skip to the JOBA card.

Field	Variable	Value	Description
1		JOB4	Card identification
2	MAXSTD(I)	+	Number of maximum standards values for parameter I ($\leq$10).
3	MINSTD(I)	+	Number of minimum standards values for parameter I ($\leq$10).
4	MAXOBS(I)	+	Number of maximum observed values for parameter I ($\leq$50).
5	MINOBS(I)	+	Number of minimum observed values for parameter I (<50).

*There are NPAR (JOB1 card, field 2) JOB4 cards. The order of these cards must correspond to the order of the JOB2 cards.

MXSTD

TABLE IV-1
(CONTINUED)

Maximum Standards Card* - Include only if NOPT (OPTION card, field 2) = 0 or 2, and if MAXSTD(I) (JOB4 card, field 2) > 0. If NOPT=1, skip to the JOBA card. Coliform values are input as log MPN/100 ml.

Field	Variable	Value	Description
1		MXSTD	Card identification.
2	STDMAX(J,I)	+	Maximum standards value for Jth standard (where J varies from 1 to MAXSTD(I)) and for Ith parameter.
3	RVMIXS(J,I)	+	River mile where above standard ends.**

*There are MAXSTD(I) (JOB4 card, field 2) MXSTD cards.

**Standards are plotted as step functions.

TABLE IV-1
(CONTINUED)

Minimum Standards Card* - Include only if NOPT (OPTION card, field 2) = 0 or 2, and if MINSTD(I) (JOB4 card, field 3) > 0. If NOPT=1, skip to the JOBA card. Coliform values are input as log MPN/100 ml.

Field	Variable	Value	Description
1		MNSTD	Card identification.
2	STDMIN(J,I)	+	Minimum standards value for Jth standard (where J varies from I to MINSTD(1)) and for Ith parameter.
3	RVMINS(J,I)	+	River mile where above standard ends.**

*There are MINSTD(I) (JOB4 card, field 3) MNSTD cards.

**Standards are plotted as step functions.

MXOBS

TABLE IV-1
(CONTINUED)

Maximum Observations Card* - Include only if NOPT (OPTION card, field 2) = 0 or 2, and if MAXOBS(I) (JOB4 card, field 4) > 0. If NOPT=1, skip to the JOBA card. Coliform values are input as log MPN/100 ml.

Field	Variable	Values	Description
1		MXOBS	Card identification.
2	OBSMAX(J,I)	+	Maximum observed value for Jth observation (where J varies from 1 to MAXOBS(I)) and for Ith parameter.
3	RVMIXO(J,I)	+	Corresponding river mile where the above observation was taken.

*There are MAXOBS(I) (JOB4 card, field 4) MXOBS cards.

**Units of observed data are same as on tape, except for streamflow, as specified earlier by IFLOW on the JOB1 card, field 9.

TABLE IV-1
(CONTINUED)

Minimum Observations Card* - Include only if NOPT (OPTION card, field 2) = 0 or 2, and if MINOBS(I) (JOB4 card, field 5) > 0. If NOPT=1, skip to the JOBA card. Coliform values are input as log MPN/100 ml.

Field	Variable	Value	Description
1		MNOBS	Card identification.
2	OBSMIN(J,I)	+	Minimum observed value for Jth observation (where J varies from 1 to MINOBS(I)) and for Ith parameter.
3	RVMINO(J,I)	+	Corresponding river mile where the above observation was taken.

*There are MINOBS(I) (JOB4 card, field 5) MNOBS cards.

After this card has appeared MINOBS(I) times, the MXSTD, MNSTD, MXOBS, and MNOBS cards are repeated as a group for each parameter specified on the JOB2 card.

If NOPT=0 (field 2 of the OPTION card), this ends the sequence of input cards.

JOBA

TABLE IV-1

(CONTINUED)

Job Card A* - Include this and the remaining sequence of cards only if NOPT (OPTION card, field 2) = 1 or 2. If NOPT=1, this JOBA card directly follows the OPTION card. If NOPT=2, this card follows the MNOBS card.

Field	Variable	Value	Description
1		JOBA	Card identification.
2	NPAR	+	Number of parameters to be examined.
3	MAXMIN	0	Plots containing minimum critical values only will be generated.
		1	Plots containing maximum critical values only will be generated.
		2	Plots containing both maximum and minimum critical values will be generated.
4	IFLOW	0	Equals 0 if flow data are in cfs.**
		1	Equals 1 if flow data are in m^3/s.**
5	CLNGTH	+	Length of horizontal axis in inches.
6	RVMIU	+	Location of most upstream river mile to be plotted.
7	RVMID	+	Location of most downstream river mile to be plotted.

*Even though some variable names appearing on this JOBA card are the same as on the JOB1 card, these variables can take on different values if specified by the user.

**If there are no flow data IFLOW can be any integer value.

TABLE IV-1
(CONTINUED)

Job Card B* - Include only if NOPT (OPTION card, field 2) = 1 or 2. If NOPT=0, no further input cards are required.

Field	Variable	Value	Description
1		JOBB	Card identification.
2	IPAR(I)	+	Order of each parameter for which a plot is to be generated.**

*There are NPAR (JOBA card, field 2) JOBB cards.

**This parameter is also the location in an array where the parameter information will be stored. Specify IPAR as though the parameters were stored on the tape containing the simulated output.

Job Card C† - Include only if NOPT (OPTION card, field 2) = 1 or 2. If NOPT=0, no further input cards are required.

Field	Variable	Value	Description
1		JOBC	Card identification.
2-4	GRLBLE(1,I)... GRLBLE(20,I)††	alpha(A1)	A 20 character title for the horizontal axis for parameter I.
4-6	YLBUL(1,I)... YLBUL(15,I)††	alpha(A1)	A 15 character title for the vertical axis for parameter I.

†There are NPAR (JOBA card, field 2) JOBC cards.

††GRLBLE ends in field 4 and YLBUL begins in field 4.

TABLE IV-1
(CONTINUED)

Job Card D* - Include only if NOPT (OPTION card, field 2) = 1 or 2. If NOPT = 0, no further input cards are required.

Field	Variable	Value	Description
1		JOBD	Card identification.
2	MAXSIM(I)	+	Number of maximum values for parameter I ($\leq$ 50).
3	MINSIM(I)	+	Number of minimum values for parameter I ($\leq$ 50).

*There are NPAR (JOBA card, field 2) JOBD cards.

TABLE IV-1
(CONTINUED)

Maximum Values Card* - Include only if NOPT (OPTION card, field 2) = 1 or 2. If NOPT = 0, no further input cards are required. Coliform values are input as log MPN/100 ml.

Field	Variable	Value	Description
1		MXSIM	Card identification.
2	RVMIX	+	River mile where these points are to be plotted.
3	SIMMAX(J,I)	+	Jth maximum value (where J varies from 1 to MAXSIM(I)) for parameter I.
4	ERRMAX(J,I)	+	The mean error associated with SIMMAX(J,I)
5	STDMAX(J,I)	+	The standard deviation associated with ERRMAX(J,I).

*There are MAXSIM(I) (JOBD card, field 2) MXSIM cards.

MNSIM

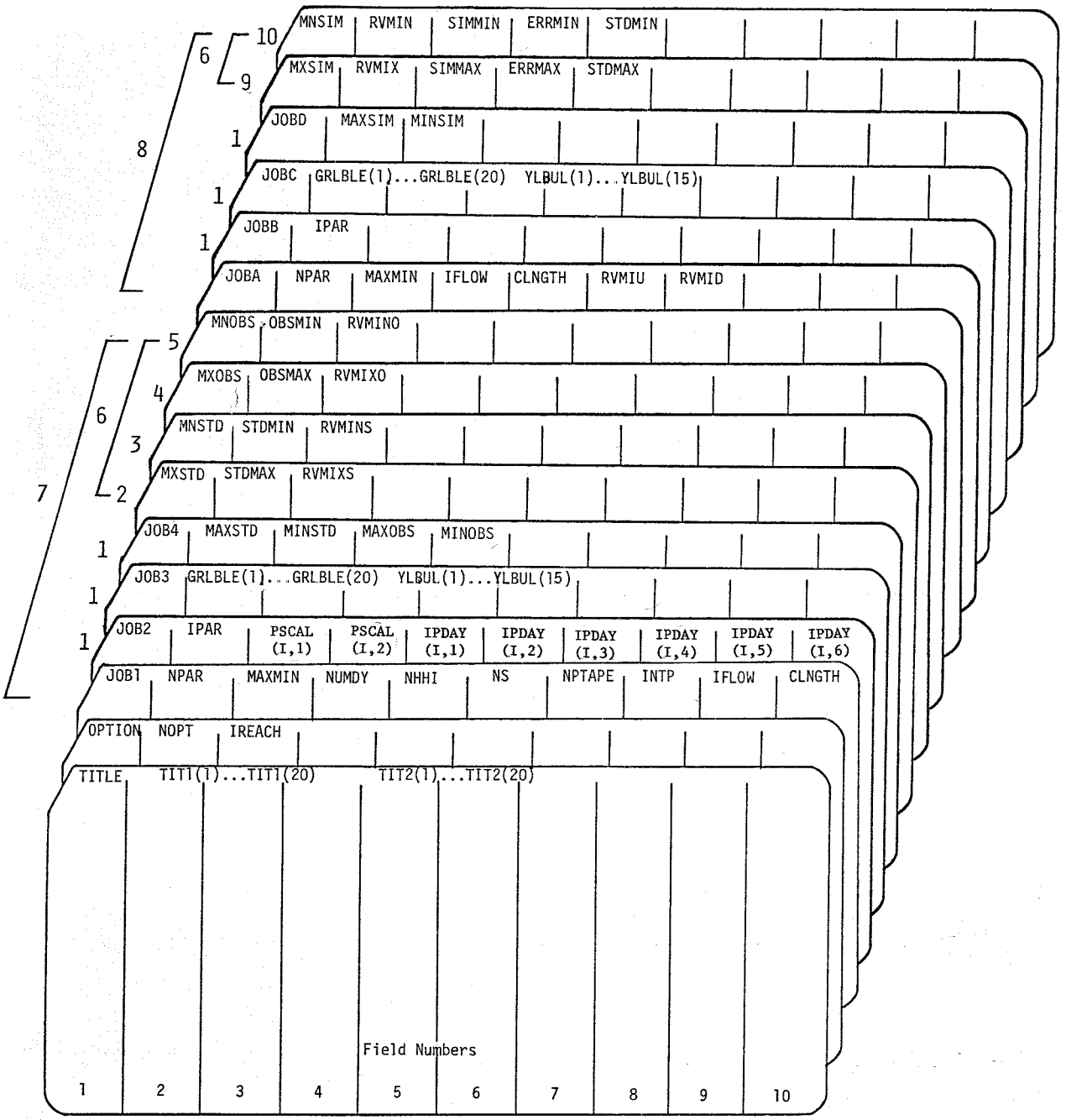
TABLE IV-1
(CONTINUED)

Minimum Values Card* - Include only if NOPT (OPTION card, field 2) = 1 or 2. Coliform values are input as log MPN/100 ml.

Field	Variable	Value	Description
1		MNSIM	Card identification.
2	RVMIN	+	River mile where these points are to be plotted.
3	SIMMIN(J,I)	+	Jth minimum value (where J varies from 1 to MINSIM(I)) for parameter I.
4	ERRMIN(J,I)	+	The mean error associated with SIMMIN(J,I).
5	STDMIN(J,I)	+	The standard deviation associated with ERRMIN(J,I).

*There are MINSIM(I) (JOBD card, field 3) MNSIM cards.

After the MNSIM card is repeated the proper number of times, the cards MXSIM and MNSIM are repeated as a group for each parameter.



NOTE 1. There are NPAR (JOB1 card and JOBA card, field 2) of these cards.
NOTE 2. There are MAXSTD (JOB4 card, field 2) MXSTD cards.
NOTE 3. There are MINSTD (JOB4 card, field 3) MNSTD cards.
NOTE 4. There are MAXOBS (JOB4 card, field 4) MXOBS cards.
NOTE 5. There are MINOBS (JOB4 card, field 5) MNOBS cards.
NOTE 6. This card group is repeated for each parameter specified on the JOB2 card.
NOTE 7. This sequence of cards is included only if NOPT = 0 or 2.
NOTE 8. This sequence of cards is included only if NOPT = 1 or 2.
NOTE 9. There are MAXSIM (JOBD card, field 2) MXSIM cards.
NOTE 10. There are MINSIM (JOBD card, field 3) MNSIM cards.

Figure IV-2. Card Sequence for the Water Quality Versus Distance Plotting Program

Application of Plotting Program

This plotting program has been applied to reach 3 of the Middle Oconee River (river mile 31.5 to 17.0) near Athens, Georgia using simulated results obtained during a study of the river from 1 October 1970 through 31 October 1970. The observed data that are used for this test case are hypothetical and are used to illustrate the program's capabilities.

Input

Figure IV-3 shows the input data used for this application. The TITLE card shows that reach 3 of the Oconee River is being analyzed. Field 2 of the next card (OPTION card) shows that the test case will illustrate both types of plots (Type 1 and Type 2) that the program is capable of generating, since NOPT=2. Hence the full complement of cards (those required to generate both plots) are needed as input.

The JOB1 card is used to specify plot characteristics and to specify needed information contained in the tape. As shown in field 2 of this card, five parameters are chosen for plotting (NPAR=5). The order that each of these parameters appears on tape is shown on the five consecutive JOB2 cards that follow (which show that the parameters of interest are the second, fifth, sixth, eighth, and eleventh parameters on tape). Following these five cards appear five JOB3 cards that show the names of each of the parameters (which will appear as part of the horizontal axis title) and their associated units (which will appear as the vertical axis title).

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQPROF DATE

REQUESTED BY R.G. WILLEY PREPARED BY CHECKED BY PAGE 1 OF 3

	1	2	3	4	5	6	7	8	9	10
TITLE	OCONEE RIVER, GA., REACH 3									
OPTION	2	3								
JOB1	5	2	31	2	30	11	20	Ø	14	
JOB2	2									
JOB2	5									
JOB2	6									
JOB2	8									
JOB2	11									
JOB3	WATER TEMPERATURE		DEG C							
JOB3	NITRATE		MG/L AS N							
JOB3	PHOSPHATE		MG/L AS P							
JOB3	LOG COLIFORMS		LOG MPN/100ML							
JOB3	BOD5		MG/L							
JOB4	3	1	8	Ø						
JOB4	4	Ø	5	5						
JOB4	4	Ø	5	Ø						
JOB4	1	Ø	2	Ø						
JOB4	2	Ø	Ø	Ø						
MXSTD	27	29.5								
MXSTD	29	23.5								
MXSTD	31	17.Ø								
MNSTD	9	17.Ø								
MXOBS	24.Ø	30.Ø								
MXOBS	26.Ø	27.5								
MXOBS	26.Ø	24.5								
MXOBS	27.Ø	23.Ø								
MXOBS	25.Ø	20.Ø								
MXOBS	25.Ø	19.Ø								
MXOBS	25.Ø	18.Ø								
MXOBS	25.Ø	17.Ø								

Temperature

SPK FORM 29 JUN 70 321a

Figure IV-3. Coding Sheets Showing Sample Input Data for Water Quality Versus Distance Plotting Program

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQPROF DATE

REQUESTED BY R. G. WILLEY PREPARED BY CHECKED BY PAGE 2 OF 3

	1	2	3	4	5	6	7	8	9	10
Nitrate	MXSTD	.7	27.0							
	MXSTD	.8	22.5							
	MXSTD	.9	20.0							
	MXSTD	1.0	17.0							
	MXOBS	.65	29.0							
	MXOBS	.823	26.3							
	MXOBS	1.1	21.0							
	MXOBS	1.22	18.0							
	MXOBS	1.3	17.0							
	MNOBS	.5	30.0							
	MNOBS	.5	27.0							
	MNOBS	.4	23.5							
	MNOBS	.3	20.1							
	MNOBS	.2	17.2							
Phosphate	MXSTD	.1	27.0							
	MXSTD	.2	22.5							
	MXSTD	.3	20.0							
	MXSTD	.4	17.0							
	MXOBS	.091	29.0							
	MXOBS	.161	26.2							
	MXOBS	.321	24.5							
	MXOBS	.440	21.6							
	MXOBS	.441	17.0							
Log Coliforms	MXSTD	3.38	17.0							
	MXOBS	4.0	28.0							
	MXOBS	4.5	21.0							
BOD_5	MXSTD	5.0	24.0							
	MXSTD	4.0	17.0							
	JOBA	1	2	0	14	31.5	17.0			
	JOBB	2								

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Figure IV-3 (Continued)

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM WQPROF DATE

REQUESTED BY R.G. WILLEY PREPARED BY CHECKED BY PAGE 3 OF 3

	1	2	3	4	5	6	7	8	9	10
JOBC	WATER TEMPERATURE	DEG C								
JOBD		5,	5,							
MXSIM		31.5,	21.0,	0.4,	0.7,					
MXSIM		29.0,	24.4,	0.2,	0.7,					
MXSIM		25.5,	26.0,	0.1,	1.1,					
MXSIM		19.5,	25.0,	-0.1,	0.6,					
MXSIM		17.0,	24.9,	-0.5,	0.2,					
MNSIM		31.5,	9.3,	0.4,	0.7,					
MNSIM		29.0,	8.1,	0.2,	0.7,					
MNSIM		25.5,	7.2,	0.1,	1.1,					
MNSIM		19.5,	8.0,	-0.1,	0.6,					
MNSIM		17.0,	8.4,	-0.5,	0.2,					

Temperature

SPK FORM 29 JUN 70 321a

Figure IV-3 (Continued)

Returning to the JOB1 card to complete its description, MAXMIN in field 3 has the value of 2, indicating the user has chosen to plot both maximum and minimum simulated values for each of the five parameters chosen. Fields 4 through 8 contain information related to the tape. In particular field 4 shows there are 31 days of simulated data on tape (NUMDY), two hours between stored values (NHHI), 30 nodes within the study reach (NS), and 11 parameters stored on tape (NPTAPE). Field 9 (IFLOW) shows the units of observed flow data. In this case, however, since flow data are not being plotted, IFLOW can equal 0 or 1. The last field of the JOB1 card shows that the test plots will be 14 inches in length (CLNGTH=14).

The JOB4 card specifies the number of maximum and minimum standards, and the number of maximum and minimum observations, for each parameter to be examined. Since five parameters are to be examined, five JOB4 cards are present. The first JOB4 card relates to water temperature, and shows that three maximum standards and one minimum standard exists in this test case. Also, eight observations of maximum temperature and none of minimum temperature are to be plotted.

Following the JOB4 card are the following four card types: MXSTD, MNSTD, MXOBS, and MNOBS. Each of these card types appears the number of times for which standards and observations have been specified on each JOB4 card. For example, the JOB4 card for temperature shows that 3 MXSTD, 1 MNSTD, 8 MXOBS, and 0 MNOBS cards must be present to fulfill the requirements of the JOB4 card.

Each of these four card types (MXSTD through MNOBS) contains a standard or observation value, and the associated river mile. In the case of the standards cards, the river mile indicates the end

point of that standard. For example, the first MXSTD card for temperature shows the maximum standard is 27°C, and is applicable from the beginning of the reach to river mile 29.5. The first MXOBS card for temperature shows that at river mile 30, the maximum observed temperature is 24.0°C. This sequence of four cards is repeated for the remaining four parameters (nitrate, phosphate, log coliforms, and BOD_5).

Since NOPT=2 (field 2 of the OPTION card), the remaining cards relate to plot Type 2. On the JOBA card, NPAR=1 indicating only 1 parameter is to be plotted. MAXMIN (field 3) indicates that both maximum and minimum critical values are to be plotted, IFLOW (field 4) specifies observed flow units and can have the value 0 or 1 since flow is not being considered, and CLNGTH (field 5) indicates the plot will be 14 inches in length. The last two fields of the card indicate the most upstream (RVMIU) and downstream (RVMID) locations to be plotted. In this case the entire study reach (river mile 31.5 to 17.0) is being plotted, but any distance is permissible as long as there are data.

On the JOBB card the IPAR specifications are used to allocate storage locations in an array. If the user desires, IPAR can be specified as 1 through NPAR.

The JOBC card is also identical with the JOB3 card, in that it specifies parameter labels for the horizontal axis (WATER TEMPERATURE in this case) and the parameter units for the vertical axis (DEG C). The JOBD card specifies the number of maximum and minimum values to be plotted for each parameter. In this case, where only temperature is being examined, there are both five maximum and five minimum values to be plotted.

The final two card types, the MXSIM and MNSIM cards each appear five times, as specified by the JOBD card. The first MXSIM card shows that the three points (SIMMAX, SIMMAX-ERRMAX, and SIMMAX-ERRMAX+STDMAX) are to be plotted at river mile 31.5. SIMMAX is 21.0°C, the maximum simulated value at that river mile, and is shown in the output of the statistical program. ERRMAX is 0.4°C and is the mean of the differences between the simulated and observed values. STDMAX, which equals 0.7°C, is the standard deviation of the difference between the observed and simulated values. Both ERRMAX and STDMAX are also contained in the output of the statistical program. The symbols used on Type 2 plot for the maximum condition are:

X SIMMAX
O SIMMAX-ERRMAX
◇ SIMMAX-ERRMAX+STDMAX

The MNSIM card contains information analogous to that of the MXSIM card. For example, the first MNSIM card shows that the first set of points is to be plotted at river mile 31.5, the minimum simulated value (SIMMIN) is 9.3°C, the mean error (ERRMIN) is 0.4°C, and the mean error standard deviation (STDMIN) is 0.7°C. In general, ERRMAX and ERRMIN are equal, as are STDMAX and STDMIN. The three points that are plotted are as follows:

X SIMMIN
O SIMMIN-ERRMIN
◇ SIMMIN-ERRMIN-STDMIN

The Type 2 plot procedure was applied in reference (3) which also includes more detailed discussion of its use.

Output

Figures IV-4 and IV-5 illustrate two Type 1 plots, the first showing water temperature and the second phosphate-phosphorus. The upper continuous line (without the asterisks) in each plot shows the maximum simulated values over the period of record at each river mile, while the lower continuous line depicts the minimum values. The water quality standards are indicated as horizontal lines containing step functions and having asterisks plotted on them. In Figure IV-4 there are both maximum and minimum temperature standards, while for phosphate only a maximum standard is specified. Observed data points are included on both plots. Maximum observed values are denoted by triangles, while minimum observed values (of which none appear) are denoted by circles.

Figure IV-6 illustrates the Type 2 plot. This plot for water temperature has both maximum and minimum critical values plotted. In this case there is not a large spread between the maximum or minimum value (shown by an 'X'), the mean error (shown by an 'O'), and the standard deviation (shown by a '◇'). In other cases the spread could be larger. The envelope curves between the points denoted by 'O' and those denoted by '◇' can be thought of as "maximum normally expected" stream temperature profiles in the case where maximum values are being plotted, and as "minim normally expected" stream temperature profiles where the minimum values are being plotted.

In contrast to the Type 1 plot which obtains its simulated water quality data from magnetic tape, the Type 2 plot has the added flexibility of plotting any type of data contained on the punched card input. The disadvantage of this type plot is that the points must be connected manually.

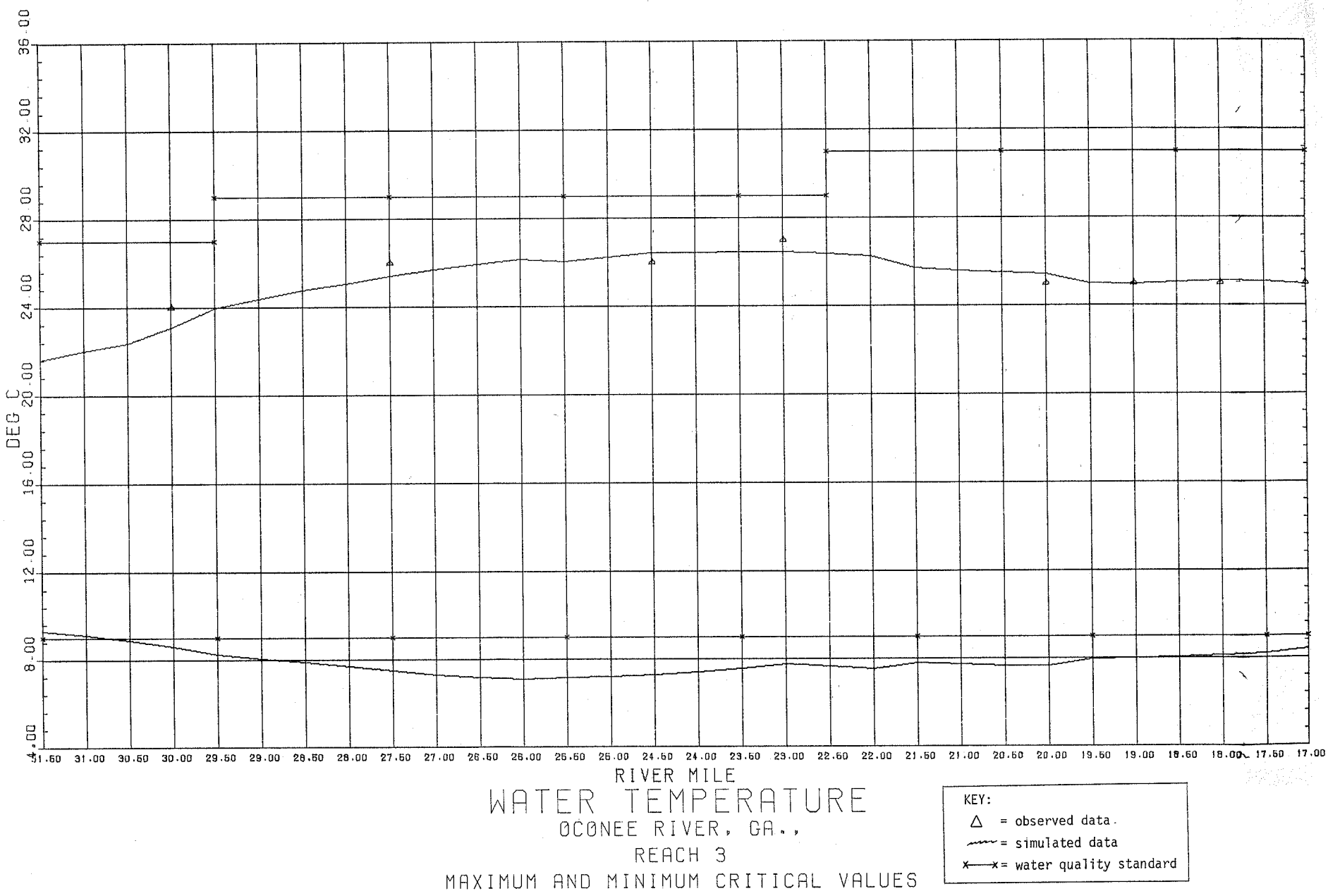

Figure IV-4. Example of Water Quality Profile Type 1 Plot Showing Water Temperature

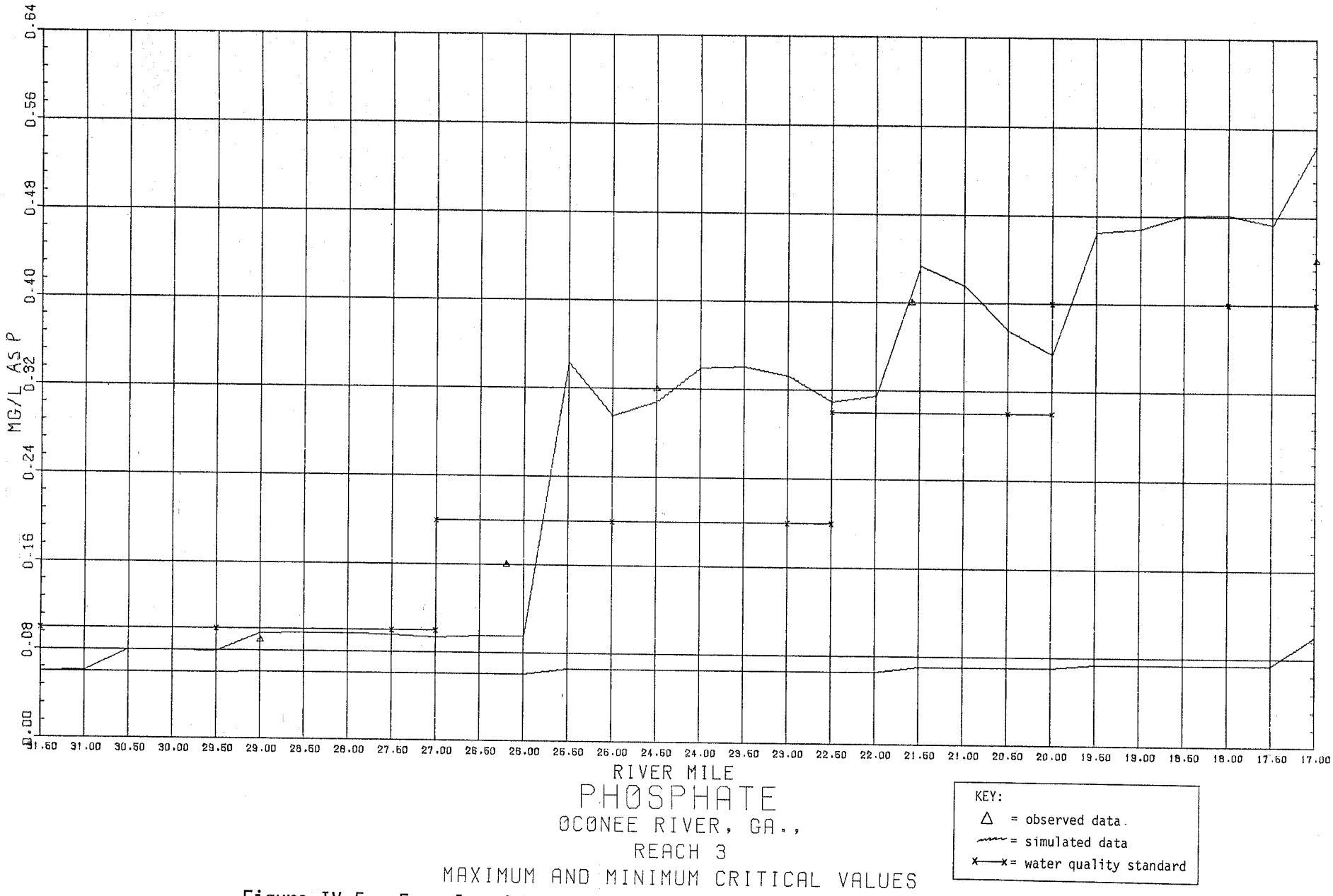

Figure IV-5. Example of Water Quality Profile Type 1 Plot Showing Phosphate

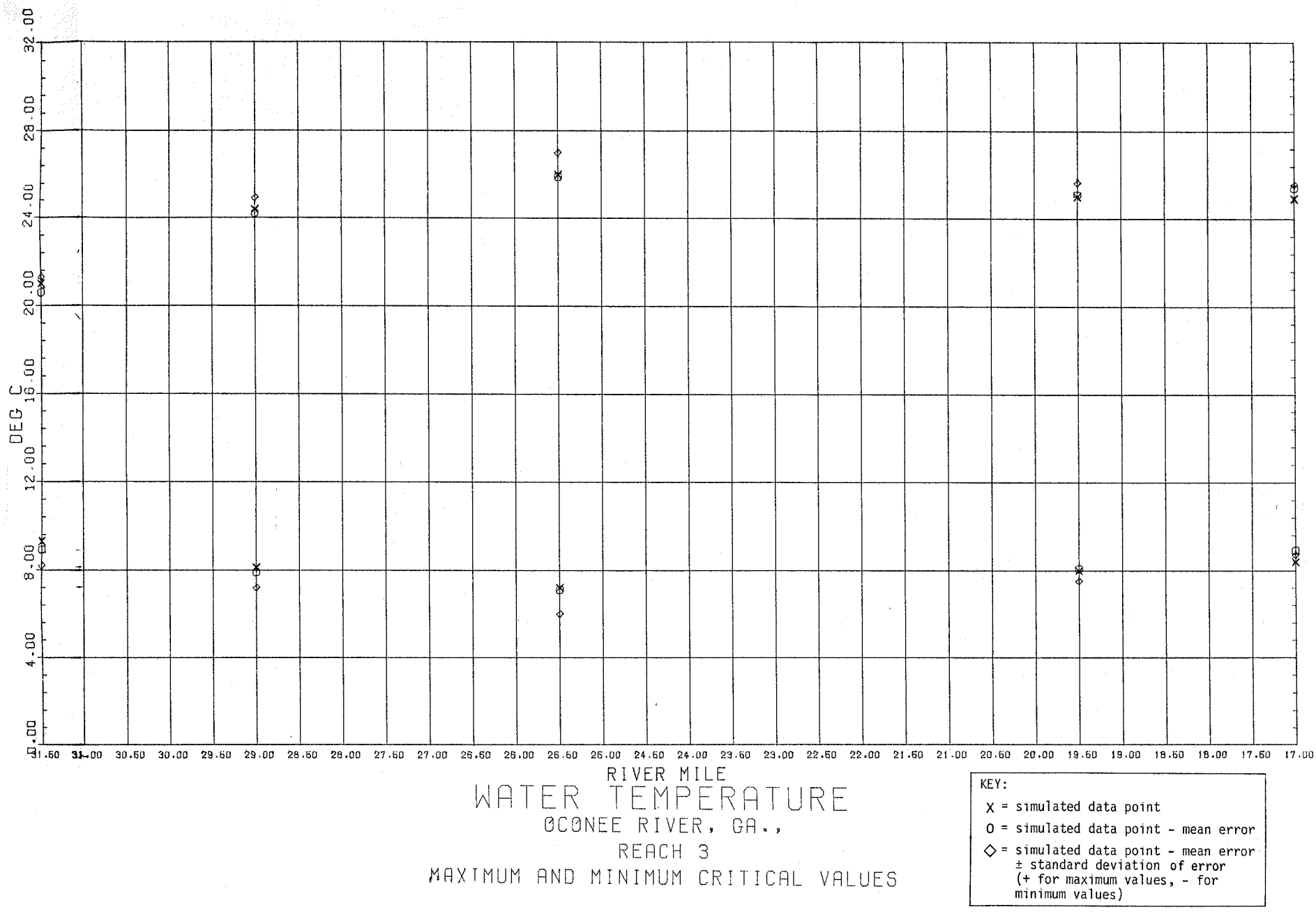

Figure IV-6. Example of Water Quality Profile Type 2 Plot Showing Water Temperature

V. REFERENCES

1. Corps of Engineers, Hydrologic Engineering Center, "Water Quality for River-Reservoir Systems," Generalized Computer Program, 1977 Version.

2. Willey, R.G., Jess Abbott, and Michael Gee, "Oconee River, Water Quality and Sediment Analysis", Corps of Engineers, Hydrologic Engineering Center, November 1977.

3. Willey, R.G., and Dennis Huff, "Chattahoochee River Water Quality Analysis", Corps of Engineers, Hydrologic Engineering Center, April 1978.

APPENDIX - JULIAN DATE CALENDAR

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JULIAN DATE CALENDAR

(PERPETUAL)

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3.
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029		088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

JULIAN DATE CALENDAR

FOR LEAP YEARS ONLY

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	061	092	122	153	183	214	245	275	306	336	1
2	002	033	062	093	123	154	184	215	246	276	307	337	2
3	003	034	063	094	124	155	185	216	247	277	308	338	3
4	004	035	064	095	125	156	186	217	248	278	309	339	4
5	005	036	065	096	126	157	187	218	249	279	310	340	5
6	006	037	066	097	127	158	188	219	250	280	311	341	6
7	007	038	067	098	128	159	189	220	251	281	312	342	7
8	008	039	068	099	129	160	190	221	252	282	313	343	8
9	009	040	069	100	130	161	191	222	253	283	314	344	9
10	010	041	070	101	131	162	192	223	254	284	315	345	10
11	011	042	071	102	132	163	193	224	255	285	316	346	11
12	012	043	072	103	133	164	194	225	256	286	317	347	12
13	013	044	073	104	134	165	195	226	257	287	318	348	13
14	014	045	074	105	135	166	196	227	258	288	319	349	14
15	015	046	075	106	136	167	197	228	259	289	320	350	15
16	016	047	076	107	137	168	198	229	260	290	321	351	16
17	017	048	077	108	138	169	199	230	261	291	322	352	17
18	018	049	078	109	139	170	200	231	262	292	323	353	18
19	019	050	079	110	140	171	201	232	263	293	324	354	19
20	020	051	080	111	141	172	202	233	264	294	325	355	20
21	021	052	081	112	142	173	203	234	265	295	326	356	21
22	022	053	082	113	143	174	204	235	266	296	327	357	22
23	023	054	083	114	144	175	205	236	267	297	328	358	23
24	024	055	084	115	145	176	206	237	268	298	329	359	24
25	025	056	085	116	146	177	207	238	269	299	330	360	25
26	026	057	086	117	147	178	208	239	270	300	331	361	26
27	027	058	087	118	148	179	209	240	271	301	332	362	27
28	028	059	088	119	149	180	210	241	272	302	333	363	28
29	029	060	089	120	150	181	211	242	273	303	334	364	29
30	030		090	121	151	182	212	243	274	304	335	365	30
31	031		091		152		213	244		305		366	31

(USE IN 1964, 1968, 1972, etc.)